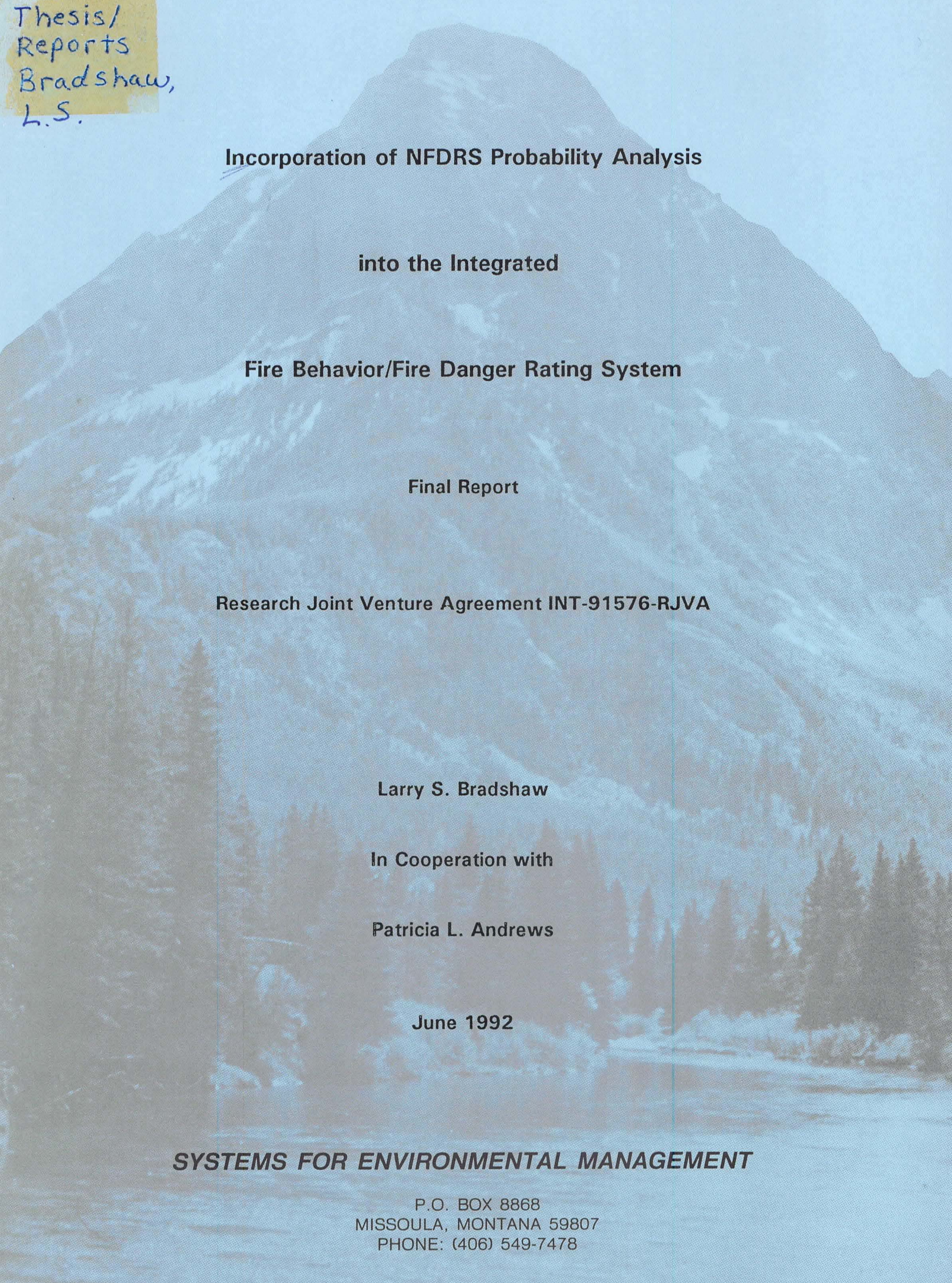

Incorporation of NFDRS Probability Analysis

into the Integrated

Fire Behavior/Fire Danger Rating System

Final Report

Research Joint Venture Agreement INT-91576-RJVA

Larry S. Bradshaw

In Cooperation with

Patricia L. Andrews

June 1992

SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

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SYSTEMS FOR ENVIRONMENTAL MANAGEMENT

A Natural Resources Research Group

Systems for Environmental Management (SEM) is a non-profit research and educational corporation based in Missoula, Montana, a regional center for natural resources agencies. Founded in 1977, SEM works cooperatively and under contract with the U.S. Forest Service, National Park Service, Bureau of Land Management, and Bureau of Indian Affairs, as well as state and academic institutions, private individuals and organizations.

SEM's diverse professional staff offers a wide range of research capabilities within the natural resources management field. The full-time staff includes specialists in fire behavior, fire history, recreation management, geography, plant ecology, forestry, meteorology, data analysis, and computer science. SEM also maintains a pool of professional affiliates that can be utilized for projects requiring additional expertise. Areas of recent research emphasis include wilderness recreation management, fire history and ecology, fire planning, and development of computerized resource management tools.

Coop Agreement
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Management

FINAL REPORT FOR RESEARCH JOINT VENTURE AGMT
#INT-91576-RJVA with
SYSTEMS FOR ENVIRONMENTAL MANAGEMENT
FS Contact: Patricia Andrews
Co-op Contact: Larry S. Bradshaw

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Preface

This report is submitted in fulfillment of section II paragraph D of Research Joint Venture Agreement INT-91576-RJVA, "Incorporation of NFDRS Probability Analysis into the Integrated Fire Behavior/Fire Danger Rating System," between the USDA, Forest Service, Intermountain Research Station and Systems for Environmental Management.

This research was supported in part by funds provided the U. S. Department of Agriculture, Forest Service, Intermountain Station, Ogden, Utah. Additional funding was provided by Systems for Environmental Management, Missoula, Montana.

Background

The Fire Behavior Research Work Unit (INT-4401) has the assigned responsibility for developing an integrated fire behavior/fire danger rating system. This is one of nine initiatives developed by the Director of Fire and atmospheric Sciences Research in the Washington Office. The initiative states: "A single, integrated system that can accommodate the full continuum of spatial/temporal resolution requirements--from National, long-range severity forecasting to real-time suppression strategy decisions on actual fires--is needed to meet the varying fire behavior information needs of wildland fire managers."

Problem #2 of the four problems outlined in the 5-year RWU 4401 description is as follows:

> The use of two systems for assessing fire potential, i.e. National Fire Danger Rating System (NFDRS) and the Fire Behavior Prediction System (FBPS), with their separate sets of fuel models, causes difficulty when fire management activities make the transition from pre-fire to real-time operation.

The first of five elements under this problem is <u>system design.</u>

> A fire analysis system will be designed that will provide increasing information about the fire environment, fire potential, and fire behavior as the fire management need increases from broad assessments, to prefire planning, to specific fire prediction. ...

Work on using logistic regression to analyze the relationship between NFDRS indexes (Deeming and others 1977) and fire occurrence was conducted under agreements with SEM: INT-87228-COA (Loftsgaarden and Andrews), INT-88296-COA (Loftsgaarden and Andrews), and INT-88343-COA (Bradshaw and Andrews). The results of those studies are detailed in the final reports for those agreements and also in Loftsgaarden and Andrews (1992). These methods of analysis have proved to be very useful and are summarized here.

Logistic models for predicting the probability of at least one fire (on a given day) as a function of one or more danger rating indexes were developed at both forest and district levels using fire weather and fire occurrence records from the Lolo National Forest (Loftsgaarden, 1987). The logistic model is of the form:

$$P(FD|x) = 1./(1.+\exp(-\beta_1 - \beta_2 * x))$$

where $P(FD|x)$ the probability of a fire day (given x), x is the value of the fire danger rating index, and β_1 and β_2 are the models intercept and slope. When P(FD) is plotted against the range of x values, a typical logistic probability curve is generated as shown in figure 1.

The initial agreement (INT-87228-COA) also explored methods of predicting 0, 1, 2, . . . or n fires per day and methods of scoring model accuracy.

The second agreement (INT-88296-COA) expanded the scope of logistic model development by using several fuel models and a second geographic area-- the National Forests of Mississippi (Loftsgaarden, 1988). This provided a basis of comparing and scoring the performance of several models on the same area-- a primary requirement of applying logistical models to fire business problems. Much effort was spent on that problem (scoring) with only partial success (Loftsgaarden, 1988). Subsequent work (Loftsgaarden and Andrews 1992) describes acceptable scoring methods suitable for application of NFDRS indexes to fire

occurrence problems.

Several menu driven computer programs were developed (during agreement INT-88296-COA) to access the remote databases required to generate logistic models (Bradshaw, 1988). Although developed exclusively for that research effort and restricted to the IFSL-Data General configuration, they performed functions useful to the general fire danger rating community.

INT-88296-COA applied the results of the previous agreements to various fire management problems, including analysis of fire danger polygons in Region 1, the Stanislaus Forest in Region 5, the National Forests of Mississippi, and BLM lands in Alaska. We also evaluated the 1988 changes in the NFDRS (Burgan 1988).

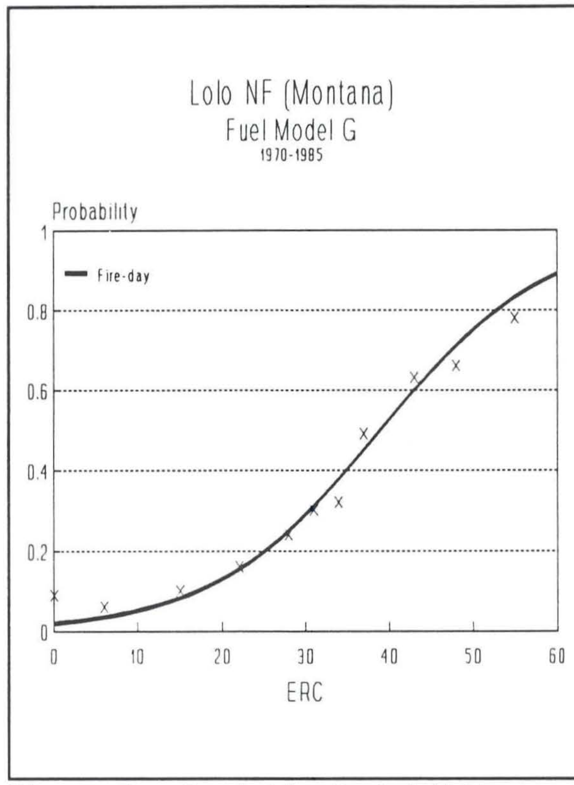

Figure 1. Logistic Probability Curve

Additionally, the remote database access programs were expanded and generalized for application in both the Forest Service's Data General and a PC environment. The programs (FCFAST) were adopted as National Systems and released by F&AM (Bradshaw and Andrews 1990). FCFAST is currently being converted to KCFAST to perform the same functions as Forest Service Databases, NFWDL (Furman and Brink, 1975), and NFODL (Yancik and Roussopoulos, 1982) are consolidated from the Department Computer Center (DCC) at Fort Collins, Colorado and are established as NIFMID (National Interagency Fire Management Integrated Database) on the DCC at Kansas City, Missouri.

Objectives

The general objective of this current research effort has been to incorporate previous work on relating fire probabilities to NFDRS indexes into the integrated fire behavior/fire danger rating system.

The specific objective were:

1. Work with members of RWU-4401 in planning and designing the integrated fire behavior/fire danger rating system. Emphasis on incorporation of the fire probability analysis into the system.

2. Develop a program that can be used by both researchers in assessing the value of various fire potential indexes for specific areas and by fire managers in decision making. Special consideration should be paid to interfaces with outside software and hardware, such as the Weather Information Management System (WIMS) under development by F&AM.

3. Apply the analysis techniques to specific problems, as determined by RWU-4401.

4. Document the results of this work in appropriate outlets in cooperation with Pat Andrews.

Program Development

We designed and began development of a system that allows fire managers to incorporate logistic models into their fire management tasks. It will be a component of the integrated fire behavior/fire danger rating system under development by RWU 4401 but does not require this system to be completed for its development. In fact, since the future system may use new indexes (such as drought codes), our methods and tools will be used to evaluate their (the indexes) correlation to fire business. Figure 2 describes the general flow of information within the system, which we call FIRES. (It should be noted that the FIRES acronym was originally established in a study by Andrews, Bevins, and Bradshaw in 1983 and has been smoldering for almost a decade.) FIRES currently provides the capability to access, retrieve, merge, and analyze index and fire files.

It generates Fire Business Analysis (FBA) files, fire-day probability functions, and fire-day cumulative distributions. It generates seasonal plots of fire danger from historical and/or current weather files, and overlays averages and extreme values. It also can overlay fire-days, large fire-days, and multiple fire-days for any year in an analysis file.

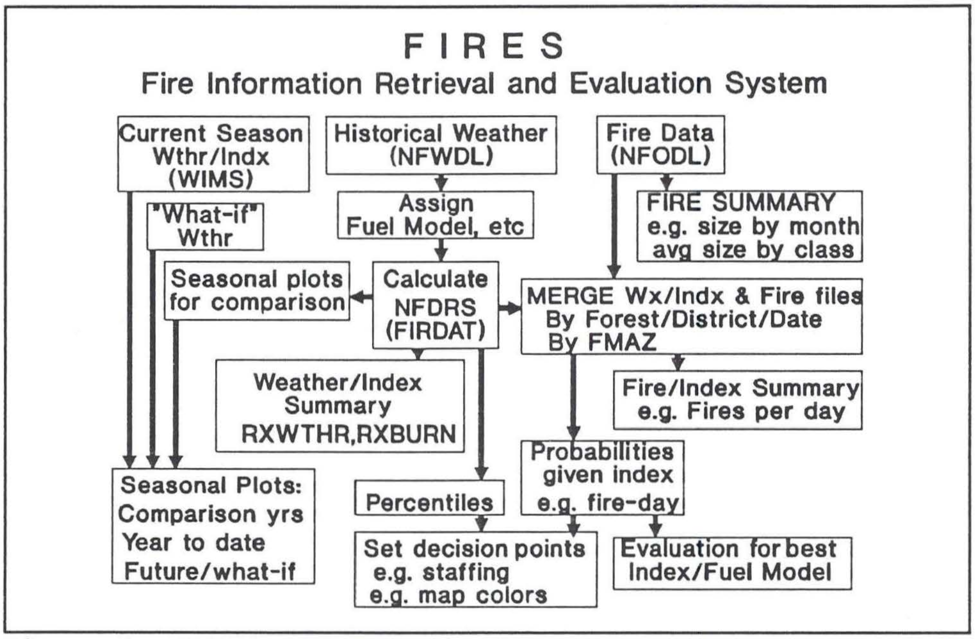

Figure 2. FIRES System Design

Finally, it will provide guidance in setting decision points and comparing the "fire business" value of different indexes. The NFDRS-FIRDAT in figure 2 can be any fire danger rating processor--the 1978 processor (Main and others, 1982), 1988 processor (Main and others, 1990), PCFIRDAT (Blanchard 1989), the next generation NFDRS, or the Canadian Forest Fire Danger Rating System. In summary, FIRES provides fire business analysis capabilities, not fire danger rating capabilities.

FIRES is still in the development and testing stage. Based on our work over the past year, and many interactions with fire managers and potential users, we offer the following features in FIRES:

- o Personal Computer based
- o Stand alone system
- o Links to future fire danger rating systems
- o Menu-driven user interface
- o Self-contained statistical and graphics functions

- o No special software requirements (e.g. SAS, ATLAS Graphic, LOTUS)
- o Interactive process for setting and displaying manning levels
- o Allows batch processing of statistical functions
- o Semi-automated access to standard Forest Service databases
- o Allows user-defined input data formats for non Forest Service data
- o Compatible with current National Systems (NFWDL, NFODL, NFMAS, WIMS)

FIRES is being written using Microsoft Fortran (Version 5.0) and uses four, third-party utility libraries. The Spindrift Library (Spindrift Laboratories, Ltd) is used for some windowing and general DOS interface functions. HISCREEN XL provides the menuing interface, and graphics functions are provided by the Quinn Curtis Library for Science and Engineering. Finally, the logistic regression is currently being done using a modified (for FIRES) version of RISK (Hamilton 1974). We anticipate replacing RISK (which uses a weighted least squares method) with a third-party program that uses more modern and robust maximum likelihood methods.

Figures 3 through 19 illustrate the current user interface, functions, and examples of the products available in FIRES.

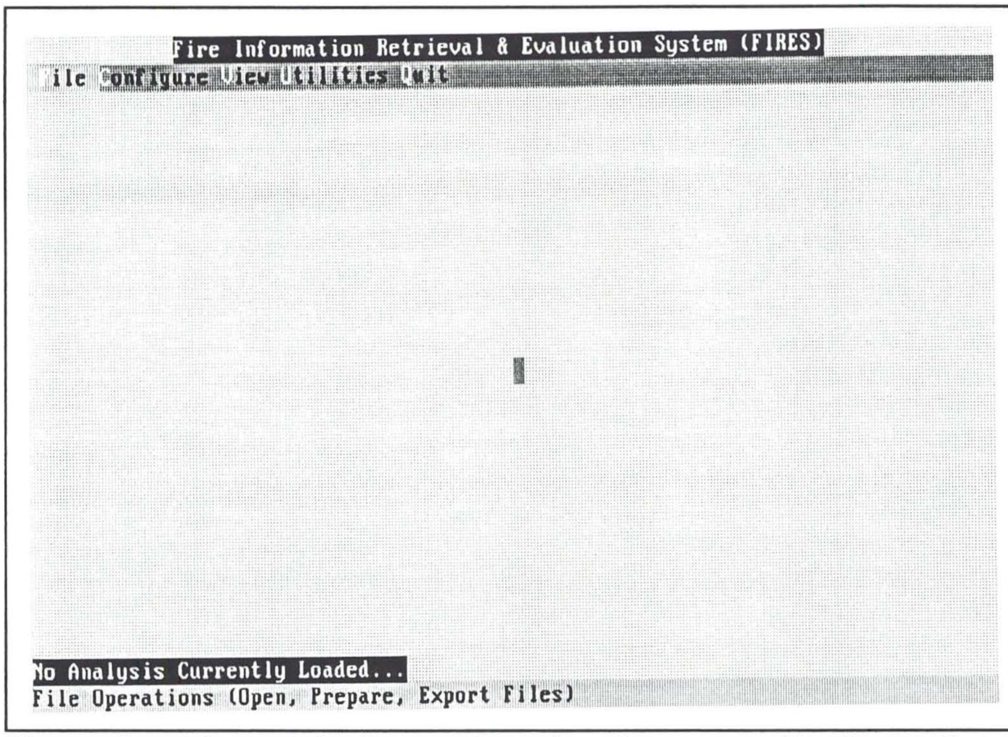

Figure 3. Fires Main Menu. Menu bar is across the top. Menu prompts are across the bottom.

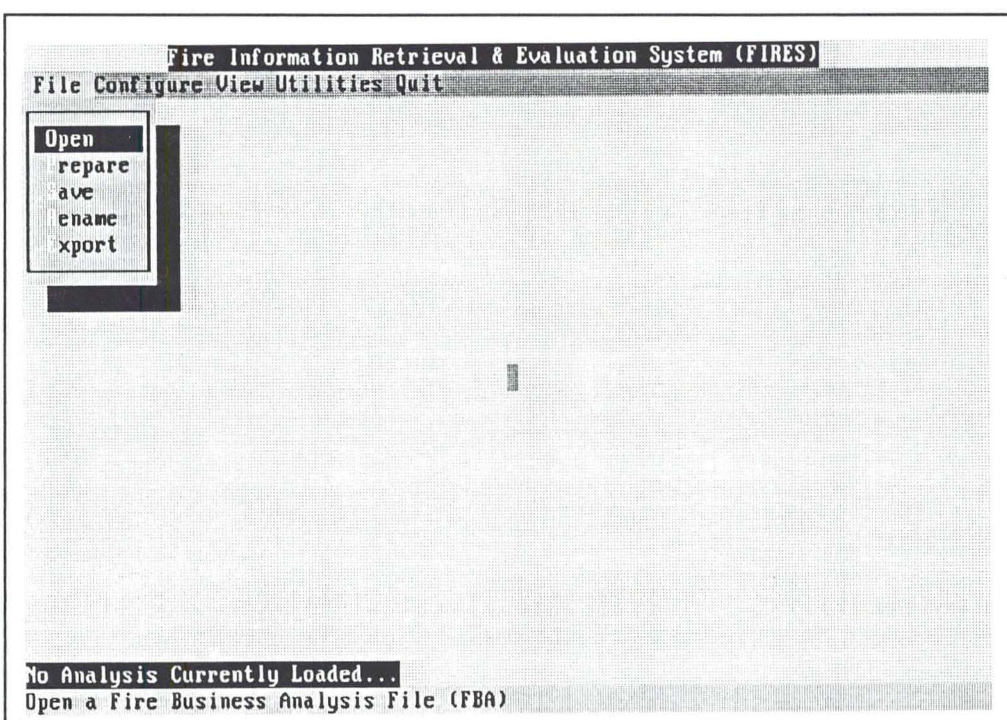

Figure 4. Files Submenu

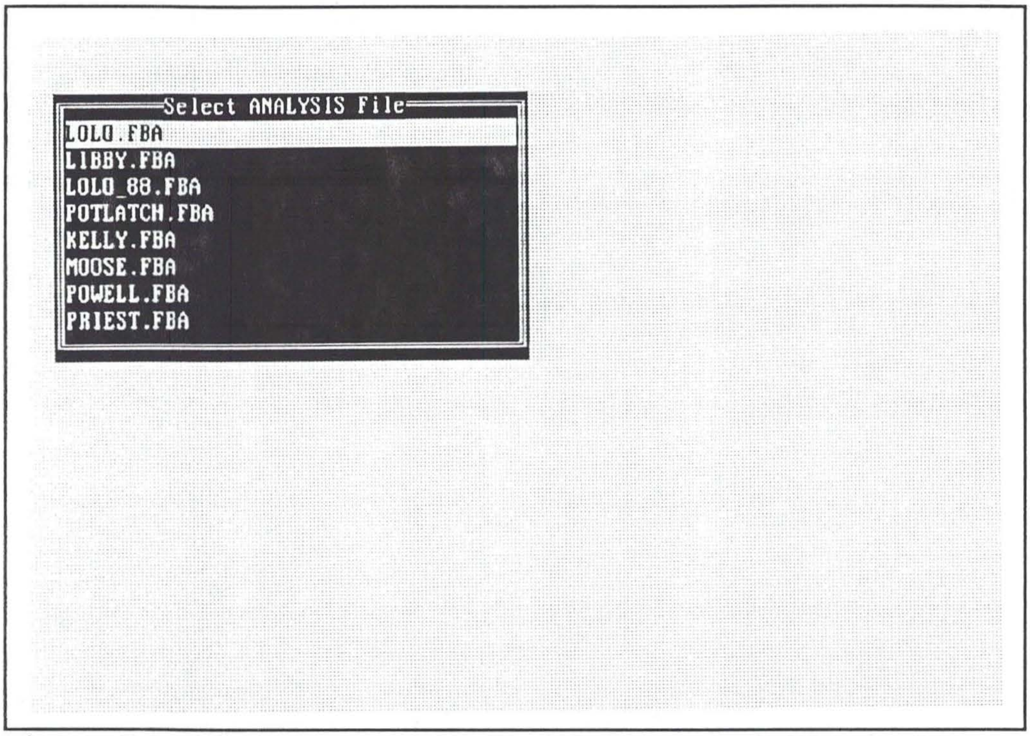

Figure 5. Files Open. Opens a pick list of Fire Business Analysis (FBA) Files.

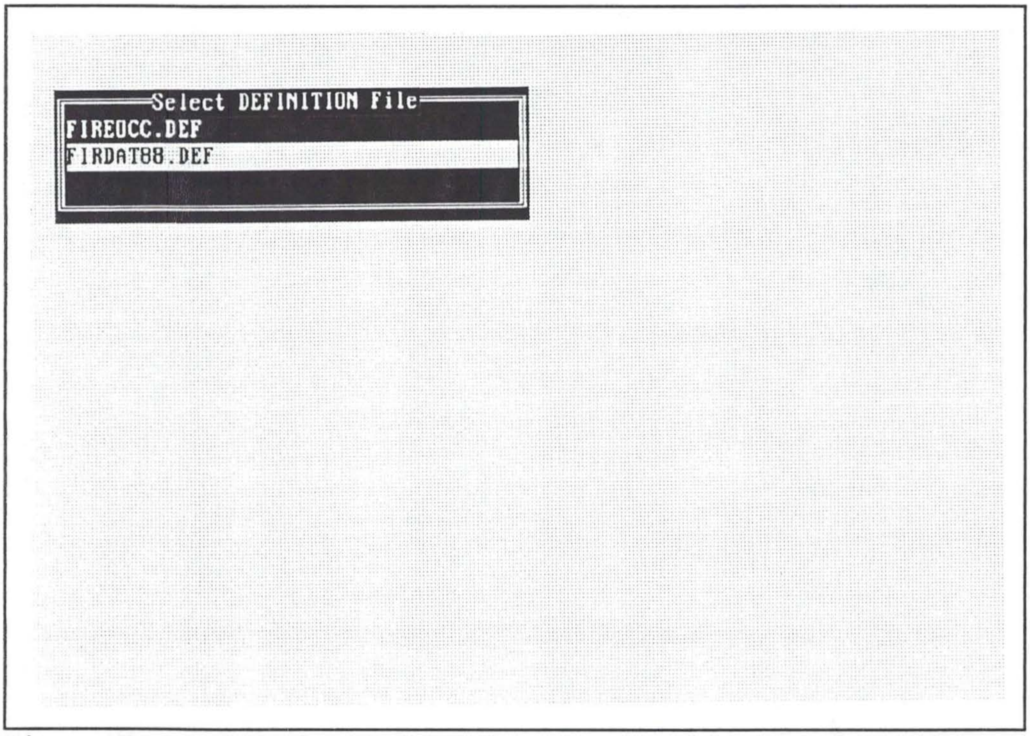

Figure 6. Users Then Select which variable definition file to use. Here FIRDAT88 is selected.

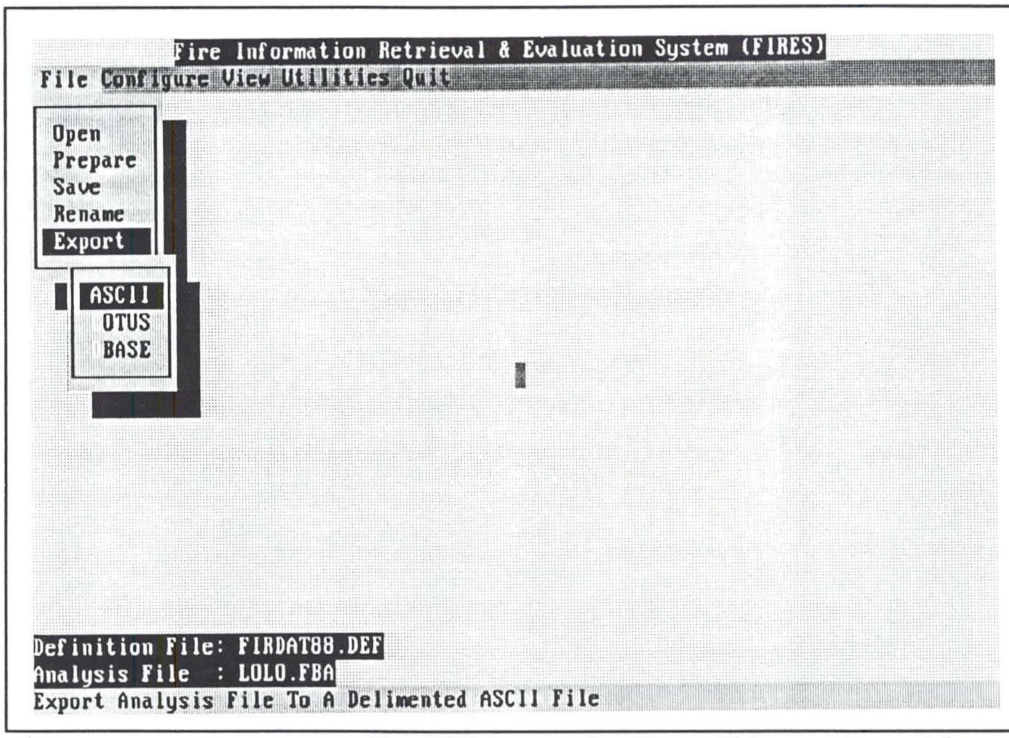

Figure 7. After returning from opening FBA files, the active files are listed above the menu prompt. FBA file can be exported for use outside of FIRES.

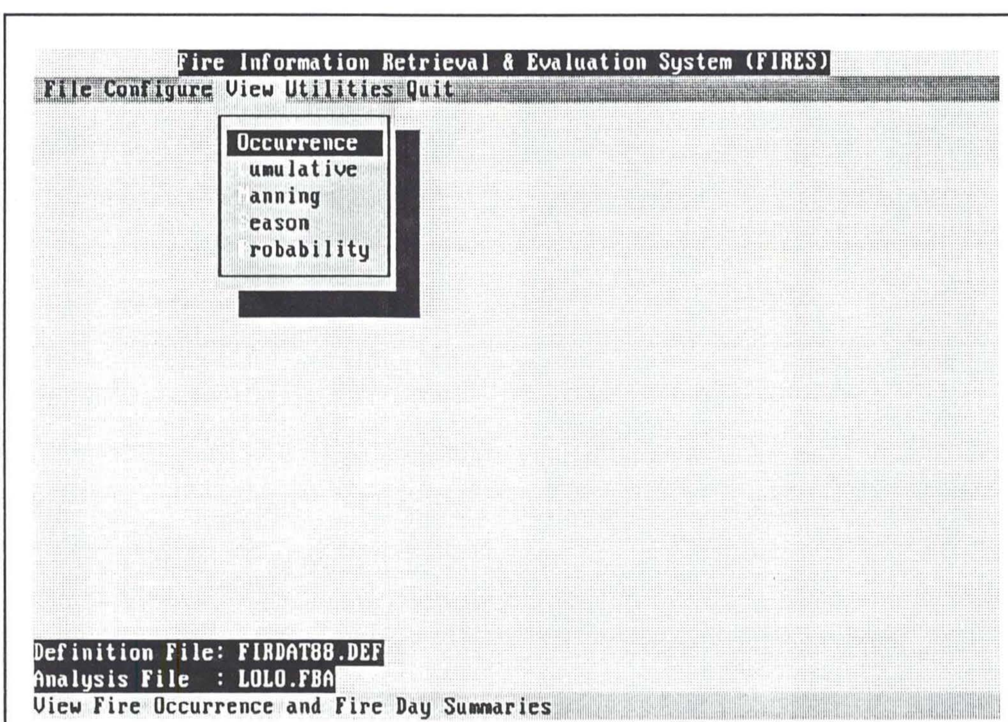

Figure 8. View submenu currently has five options.

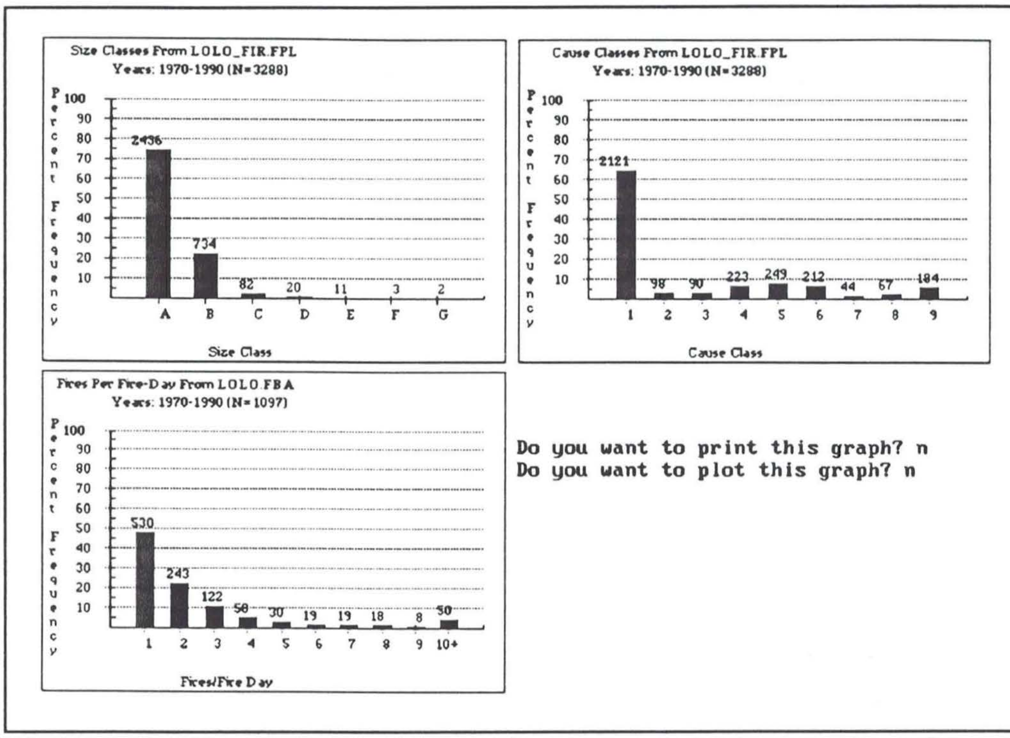

Figure 9. Example output from Occurrence Option. Fires by size, cause, and number of fires/fire-day.

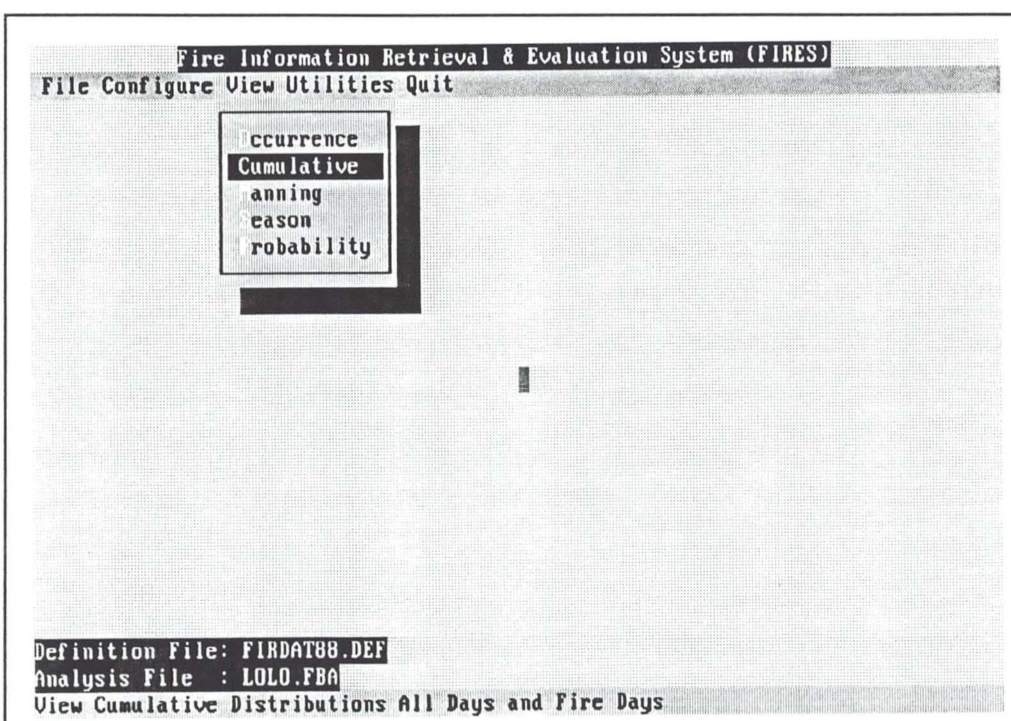

Figure 10. Selecting cumulative distributions of all days and fire-days.

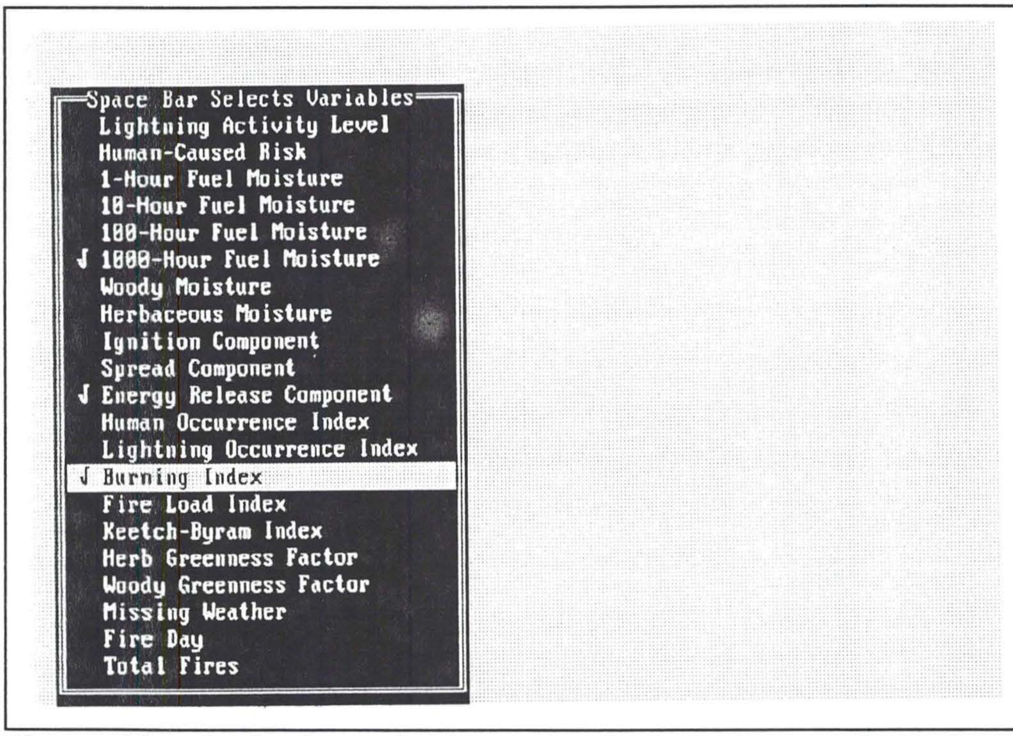

Figure 11. Analysis variables are selected via a pick list window. (1000-h, ERC, and BI are selected here.)

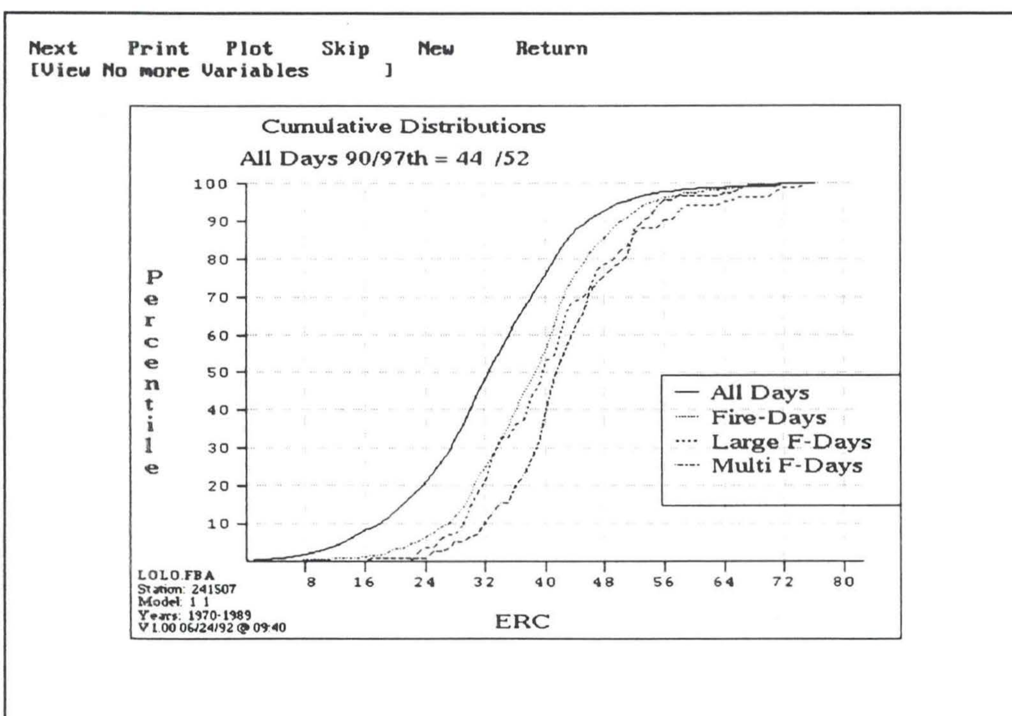

Figure 12. Example output for cumulative distributions. ERC at Lolo, for all days, fire-days, large fire-days, and multiple fire-days.

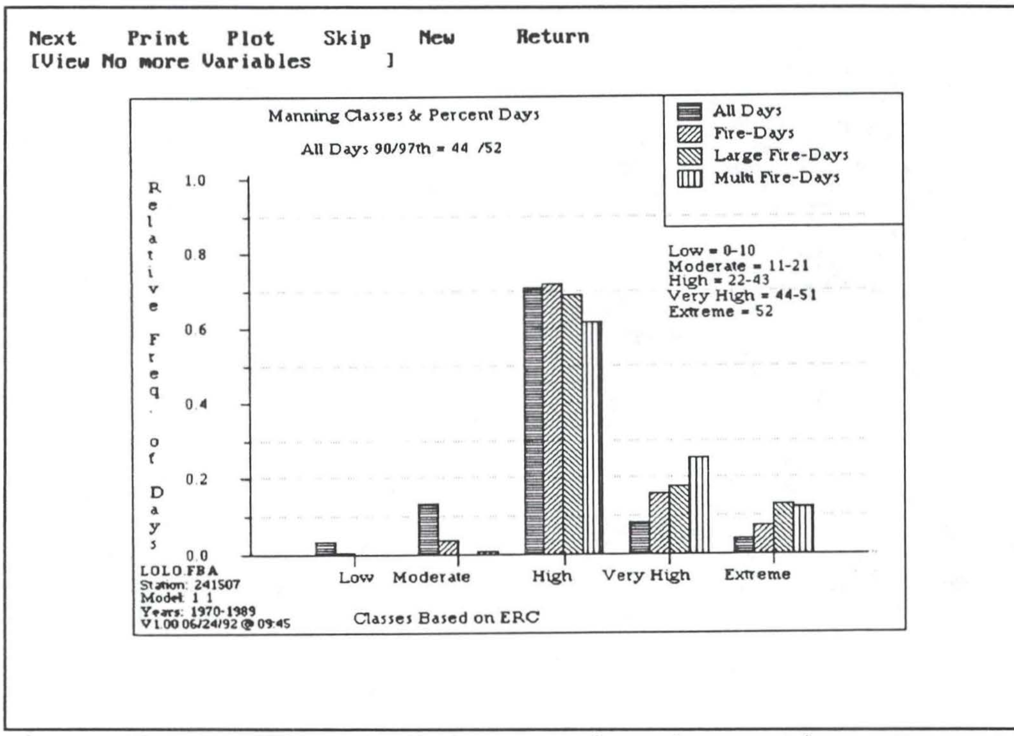

Figure 13. Example output from manning class option. Percent of days in each manning class for each day-type are shown.

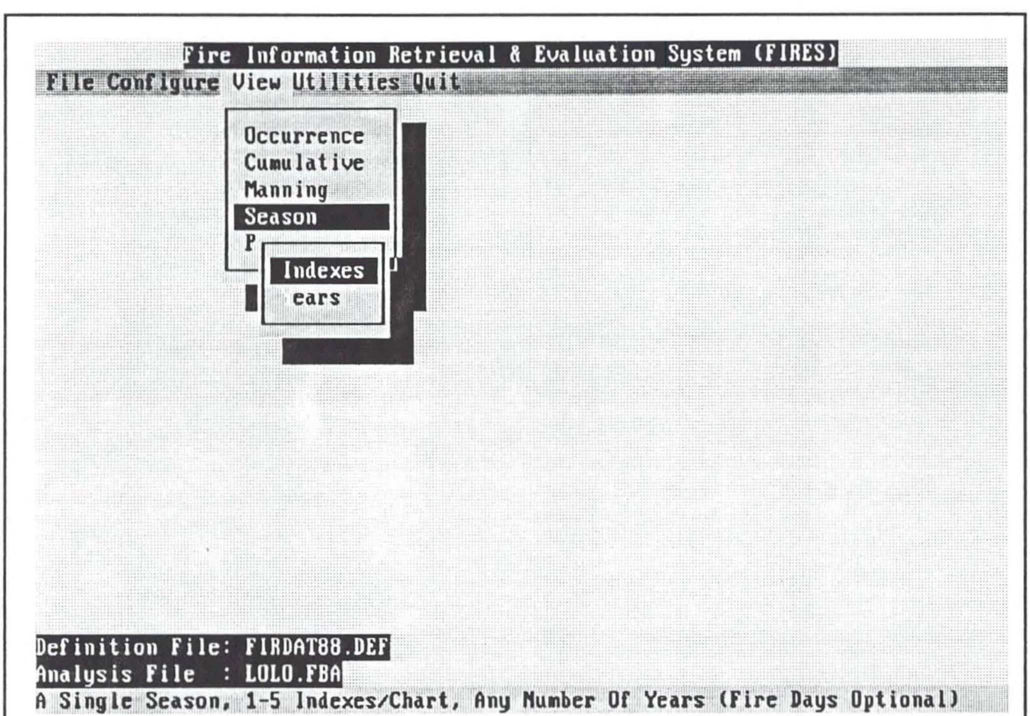

Figure 14. Season has two options. One year and several indexes/chart, or one index and several years/chart.

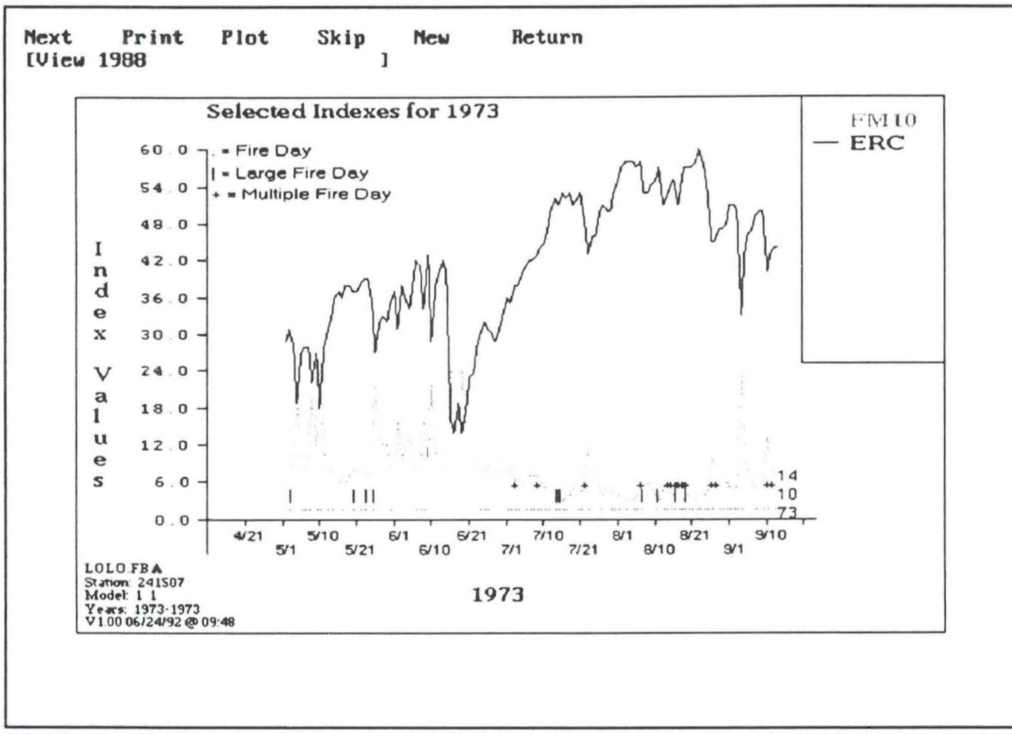

Figure 15. Example Season indexes output. 10-h moisture and ERC are shown for 1973. Prompt at top shows 1988 is next in viewing queue.

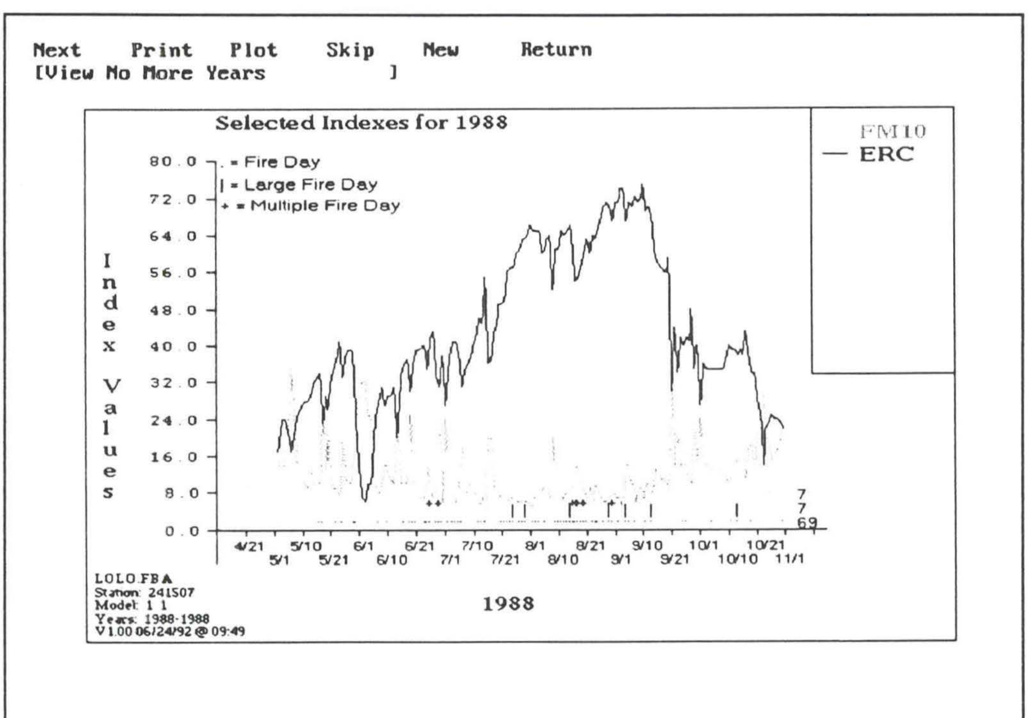

Figure 16. 10-h and ERC for 1988. Fire-days by date and type are marked and tabulated along the date axis.

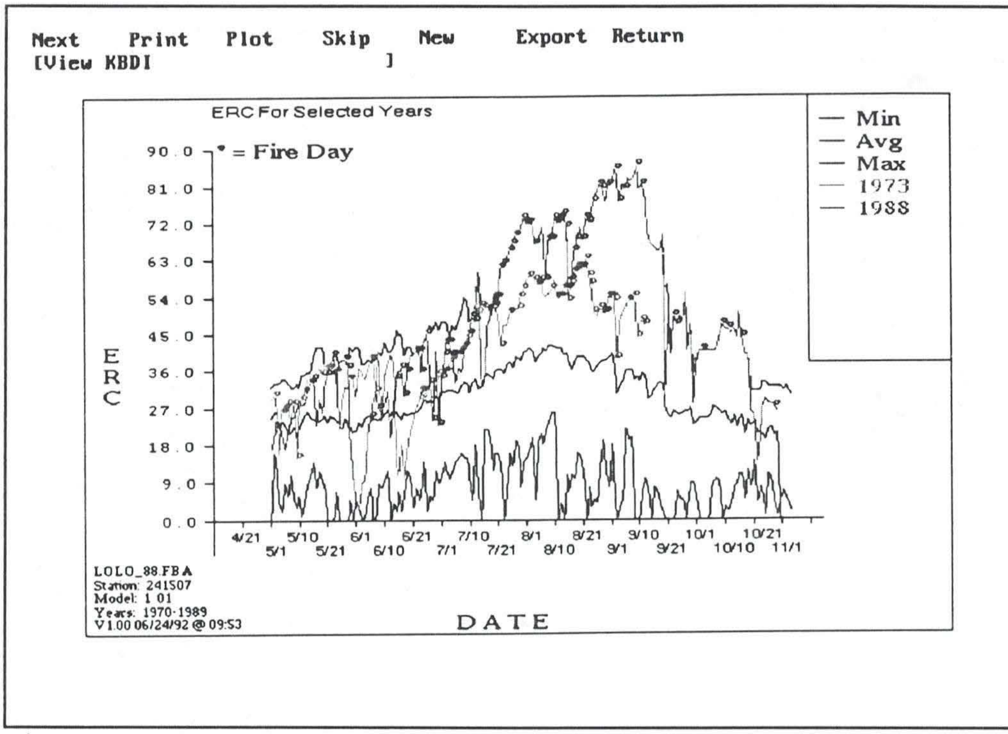

Figure 17. Example season years ERC output. Period (1970-89) daily means and extremes are plotted along with daily ERC for 1973 and 1988. Fire-days for 73 and 88 are marked.

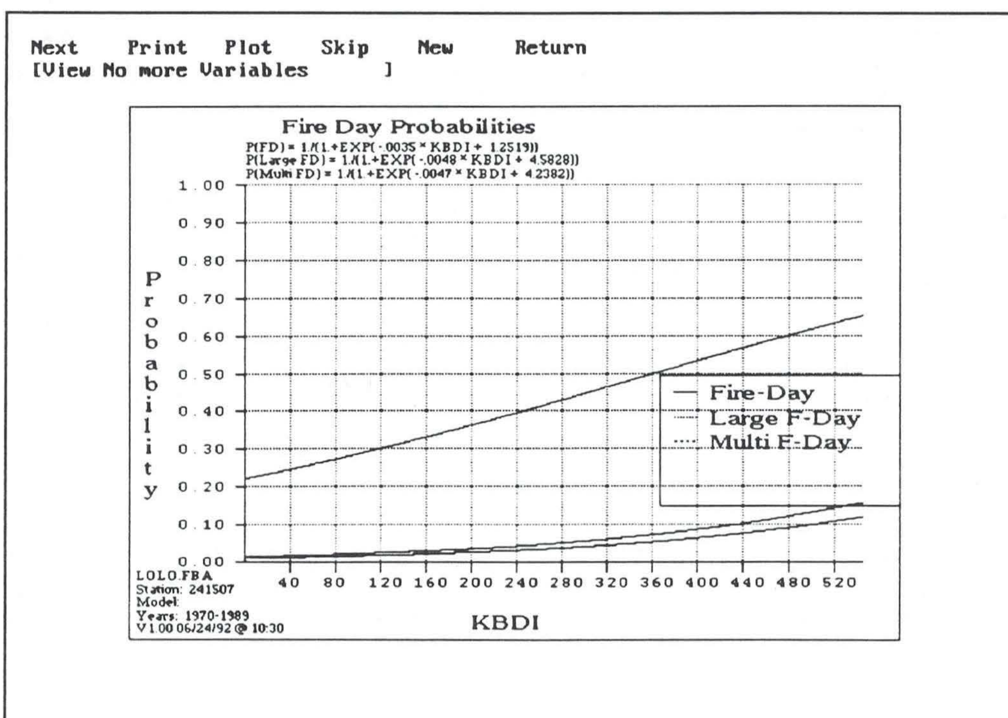

Figure 18. Example output from probability option for KDBI (drought index)

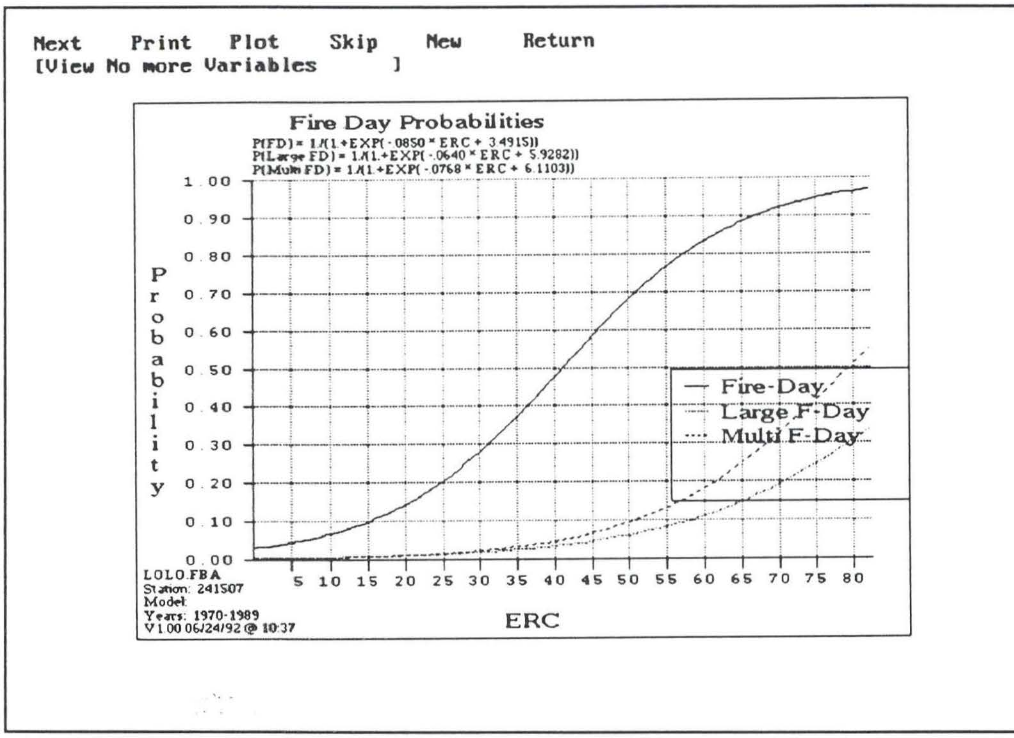

Figure 19. Example output from probability option for ERC. ERC is a better indicator of fire business than is KDBI.

Applications

We applied our analysis techniques to wildland fire occurrence in Alaska to evaluate the relationship between the United States NFDRS and the Canadian Forest Fire Danger Rating System (CFFDRS). In both the U.S. and Canadian systems, some indexes worked well and other had little relationship to fire business. The U.S. Energy Release Component (ERC, fuel model G) and the Canadian Duff Moisture Code (fuel model independent) were the best predictors. The Canadian drought code had little correlation to fire business. The data, methods and results of this study are documented in an office report by Andrews and Bradshaw which is included as Appendix A of this report.

In late 1991, the U.S. Department of Interior issued a request for proposals for a variety of topics. One topic area was "Determination of Optimum Fire Danger Planning Index." We put together a proposal, which was subsequently accepted and funded which includes expansion and application of FIRES programs and techniques. A copy of the proposal is included as Appendix B of this report.

We made formal presentations of our methods and programs to two National audiences. We presented our Alaska work to a joint Alaska Fire Council/NWCG (National Wildfire Coordinating Group) Prescribed Fire and Fire Effects Working Teem Meeting in Fairbanks, Alaska, June 1991. We presented our general methods and program design to the National Advisory Group for Fire Danger Rating (NAGFDR) in Missoula, Montana, September 1991 during a day-long introduction to the future integrated fire behavior/fire danger rating system.

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Appendix A

Alaska: Fire Danger Rating--Fire Occurrence Analysis

OFFICE REPORT

Alaska: Fire Danger Rating--Fire Occurrence Analysis

Patricia L. Andrews
Larry S. Bradshaw

August 7, 1991

Introduction

One of the studies being conducted by the Fire Behavior Research Work Unit at the Intermountain Fire Sciences Laboratory in Missoula, Montana is an analysis of the relationship between fire danger rating indexes and fire occurrence data. We believe that this work can be used to

- -Evaluate the performance of the National Fire Danger Rating System (NFDRS)
- -Give researchers a way to evaluate proposed changes to the system
- -Help fire managers choose the best fuel model and index
- -Give fire managers a way to interpret fire danger indexes
- -Provide information that a fire manager can use in setting decision points (e.g. staffing levels)

Preliminary tests using data from Montana, Mississippi, and California indicate that the approach is worthwhile. Two technical reports describing the methods are in preparation. Our current focus is on developing a program that can be used on a PC by fire managers. This work is being supported in part by the National Park Service. At the request of Rod Norum (NPS, BIFC) we used Alaska data to further test our methods. Preliminary results are summarized in this office report. Additional analysis and documentation will be done at a later date.

We looked at several fuel models and indexes from the U.S. fire danger rating system and also indexes from the Canadian danger rating system. In both the U.S. and the Canadian systems, some indexes worked well and others had little relationship to fire business. The U.S. Energy Release Component (fuel model G) and the Canadian Duff Moisture Code appear to be the "best".

Methods

It is easy to define a test of a fire behavior prediction system: predicted rate of spread or flame length are compared to observed values. Predictions are based on weather, fuel, and topography at the site of the observations. On the other hand, fire danger rating is based on an afternoon weather reading at an established site. The estimate of "fire danger" is applied to a large administrative area, which often includes a variability in fuel and topography. In any case, weather conditions change throughout the day, the fire danger index does not. "Fire danger" is a difficult term to define.

The problem is to find some observable measure of "fire danger" against which to test the performance of indexes. We, like others, have found fire-day to be a good indicator of fire business. We use logistic regression which is designed to fit a curve to zero/one data. The independent variable is the danger rating index. The dependent variable is fire-day: 1 if one or more fires are reported on that day and 0 otherwise. The result is probability of fire-day based on an index. We feel that if an index is a good indicator of "fire danger" it should be related to "fire business"-- that there will be more fire activity when fire danger is high than when it is low.

In this report we just show the results of an analysis of fire-days. We will look at large-fire-days and multiple-fire-days when we get more complete weather data.

Much of the work that we've done with Dr. Don Loftsgaarden, University of Montana Math Department, has focused on tests of fit (how well the logistic model fits the data). We'll spare you the statistics in this report. We'll stick to visual and qualitative comparison and report the technical details later.

Weather Data

Five weather stations were chosen in Alaska for the analysis: McGrath, Galena, Bettles, Fort Yukon, and Northway. Weather data before 1980 was not used because fire data was not available.

Exhibit 1 is tables of the number of weather observations available for each 10-day period for each of the 5 stations.

Exhibit 2 is a bar graph showing the percent of possible observations for each 10-day period. Only 1980-1988 are used to calculate percentage because no weather data is available for 1989-1990.

For this initial analysis we just used the Galena weather station because it had the most complete data. We hope to get more complete weather data before we continue the analysis.

Exhibit 3 shows the completeness of weather data for the Galena station for 1955-1990. We include this table to illustrate the trend of reduced emphasis on the collection and archiving of weather data.

Fire Data

We defined an analysis zone to be a 100 mile block around each weather station. The fire data was provided to us by the BLM. Data were available for 1980-1990. We used only 1980-1988 because there was no weather data for 1989-1990. The only information we used from the fire records was discovery date and final fire size. Fire data were not separated by cause or suppression strategy.

Exhibit 4 shows the number of fires by 10-day period and size class for each of the five analysis zones.

Exhibit 5 is bar graphs of this data-- number of fires by 10-day periods and fire size classes for each analysis zone.

Exhibit 6 is a table and a graph showing multiple-fire-days.

Fire Danger Rating Data

Fire danger rating indexes are calculated from the weather data discussed above. We did calculations for both the U.S. National Fire Danger Rating System and the Canadian Fire Weather Index System, part of the Canadian Forest Fire Danger Rating System (CFFDRS). We used the 78 version of NFDRS because at this time the 88 version is not operational.

Exhibits 7 and 8 are flow diagrams for those two systems. They show the input requirements for the calculations and the relationship among indexes. There are many similarities between the systems.

Exhibit 9 lists the 20 U.S. NFDRS fuel models and the properties of each. We tried 4 fuel models (Q, R, L, S) that would seem to be appropriate for Alaska. And we tried fuel model G because 1000-h fuel moisture was a good indicator of fire business and because fuel model G has a large amount of 1000-h fuel.

Following are abbreviations for the indexes:

US NFDRS	(fuel model letter will be placed in parens after index code)	
	1000-h	Thousand hour fuel moisture
	SC	Spread Component
	ERC	Energy Release Component
	BI	Burning Index
	IC	Ignition Component
	FLI	Fire Load Index
Canadian	FFMC	Fine Fuel Moisture Code
	ISI	Initial Spread Index
	DMC	Duff Moisture Code
	DC	Drought Code
	BUI	Buildup Index
	FWI	Fire Weather Index

Fire Danger/Fire Occurrence

We merged the fire and the index files to create a data file with date, danger rating indexes, and the number and final size of all fires that were discovered on that date. To get a feeling for what the indexes do over a season, we picked 1980 and 1984 to show seasonal index and associated fire days. 1980 was a low fire year and 1984 a high fire year. For the U.S. NFDRS, we plotted four indexes, ranging from "poor" to "good".

Exhibit 10 includes seasonal plots for BI(L), ERC(S), 1000-h moisture, and ERC(G). Fire-days are indicated with a "*". Remember that each of the indexes is based on the same weather data; differences are due to calculations.

Exhibit 11 shows a tabulation of index ranges and number of days in each group. It also shows observed and predicted numbers of fire-days, and fraction of fire-days. We include BI(L) and ERC(G), a poor and a good index as indicated by the relationship to fire-day, a measure of fire business.

Exhibit 12 shows the logistic regression curves for the four sample indexes. The curve is probability of a fire-day based on index. The stars are observed percent fire days for a range of index values. The number by the star is the number of days that went into the calculation of percent fire-days. Refer to Exhibit 11 for clarification.

Notice that there is a very poor relationship between BI(L) and probability of fire-day. Also notice that BI(L) was less than 5 over half of the time (170+116+113+47=446 of 840 days: 53%). Notice that the probability of a fire-day increases steadily with ERC(G). We chose ERC(G) as the "best" indicator of fire danger (from the U.S. NFDRS).

Exhibit 13 shows the percentile curves for the indexes. Percentile based on all days is currently used in fire management-- possibly the 85th, 90th, or 97th percentiles are used as decision points. We have also produced percentile curves based on fire-days, large-fire-days, and multiple-fire-days. All we'll say for now is that if those curves are to the right of the all-days percentile curve, fire business is happening on higher index days (except 1000-h which is the reverse-- lower numbers mean dryer fuel and higher fire danger).

Exhibits 14, 15, and 16 are the seasonal plots, probability curves, and percentile curves for the six Canadian indexes. Notice on the probability graphs (Exhibit 15) that there is a poor relationship between DC and probability of a fire day. The logistic regression curve is essentially a straight line: the probability of a fire-day is 8% no matter what the DC is. On the other hand, there is a very good relationship between DMC and probability of a fire-day. DMC seemed to be the "best" indicator of fire danger from the Canadian system.

Exhibit 17 is a tabulation of observed and predicted numbers and fraction of fire-days for DC and for DMC.

Conclusions

One of the purposes of initiating this study was to define a way to distinguish "good" and "poor" indicators of fire danger. We feel that the methods are appropriate for evaluating the performance of US and Canadian fire danger rating systems in Alaska.

Results indicate that either the U.S. or the Canadian danger rating system could be used successfully in Alaska.

There are too many choices in the NFDRS. Twenty fuel models and five indexes amount to 100 possibilities. Understandably a person in Alaska would choose a fuel model titled "black spruce" or "tundra" and would not try one called "pine". However the names of the fuel models aren't that important. Fuel model G has a large amount of 1000-h fuel. Energy Release Component reflects

the drying of fuels. The 1000-h fuels may be duff rather than large logs. The Canadian Duff Moisture Code is a similar index. It is noteworthy that neither ERC nor DMC include wind in the calculation. A danger rating index based on the dryness of fuels seems to be the best indicator of fire potential. Wind, of course, is an important factor in calculating fire behavior.

Future

Having written and distributed this office report on some preliminary analysis, we will now concentrate on developing a computer program for fire managers to use and on writing technical papers to document our methods. We hope that someone will be concurrently working on improving the historical data base of weather and fires for key Alaska stations. We will continue our analysis of Alaska data some time after Jan. 1992. And if there is interest we will be able to offer a test version of our program to fire managers in Alaska.

We hope that our work will help fire managers make the best possible use of currently available fire danger rating systems.

We expect to apply what we learn about what works and what doesn't work to development of future systems. We have been talking with Canadian researchers about the value of an international fire management system. We will be trying to define common ground and begin some cooperative efforts.

FIRE WEATHER

Exhibit 1

NUMBER OF OBSERVATIONS IN EACH 10-DAY PERIOD FOR: NORTHWAY

PERIOD->	MAY			JUN			JUL			AUG			SEP		
YEAR	1	11	21	1	11	21	1	11	21	1	11	21	1	11	21
1980		2	10	9	9	9	9	7	11	10	8	8			
1981		6	11	9	10	10	9	10	9	8	6				
1982			7	10	8	8	4	7	9	7	10	9	1		
1983				4		8	8	9	5	5	10	2			
1984			11	10	10	10	10	10	11	10	10	3			
1985		1	10	10	9	8	10	10	11	10	7	10			
1986		4	9	10	10	10	9	9	11	9	9	7			
1987		2	8	10	9	10	10	9	11	10	7	6			
1988			5	9	9	10	8	8							
1989															
1990															
	0	5	8	9	8	9	9	9	8	8	8	7	1	0	0

NUMBER OF OBSERVATIONS IN EACH 10-DAY PERIOD FOR: FORT YUKON

PERIOD->	MAY			JUN			JUL			AUG			SEP		
YEAR	1	11	21	1	11	21	1	11	21	1	11	21	1	11	21
1980		5	10	10	9	9	9	9	11	10	10	5			
1981		6	10	9	9	10	9	10	11	9	6				
1982				9	8	8	4	8	9	6	6	2	1		
1983			4	7	9	4	9	9	4	6	6				
1984			10	10	10	8	9	10	7	7					
1985		1	8	8	10	10	7	4	7	5		1			
1986					1										
1987		2	8	10	9	10	10	9	10	10	7	6			
1988			5	9	9	10	8	9							
1989															
1990															
	0	4	7	8	9	8	8	8	7	7	5	4	1	0	0

NUMBER OF OBSERVATIONS IN EACH 10-DAY PERIOD FOR: BETTLES

PERIOD->	MAY			JUN			JUL			AUG			SEP						
YEAR	1	11	21	1	11	21	1	11	21	1	11	21	1	11	21				
1980			5	9	9	10	8	8	10	10	10	7							
1981		3	9	9	10	10	7	10	9	7	4								
1982			7	10	8	8	4	9	9	7	10	8	1						
1983				4		1	8	9	5	5	10	2							
1984																			
1985						5	10	9	11	9	8	10							
1986					1														
1987		2	5	10	9	9	10	9	11	10	7	6							
1988			5	4	1	6	8	9											
1989																			
1990																			
	0	2	5	6	6	7	7	7	6	6	6	5	1	0	0	0	0	0	0

FIRE WEATHER (con't) *Exhibit 1 (cont)*

NUMBER OF OBSERVATIONS IN EACH 10-DAY PERIOD FOR: GALENA

PERIOD->	MAY			JUN			JUL			AUG			SEP		
YEAR	1	11	21	1	11	21	1	11	21	1	11	21	1	11	21
1980	1	5	10	10	10	9	10	9	10	8	10	4			
1981		5	10	10	10	10	9	10	10	8	5				
1982		2	11	9	8	7	4	7	9	7	10	4			
1983		3	9	10	10	10	10	8	5	6	7	1			
1984			10	10	10	9	10	10	11	10	10	3			
1985		1	9	10	9	9	10	10	10	9	8	10			
1986		4	9	10	10	10	9	9	11	9	8	7			
1987		2	8	9	9	10	10	9	11	9	7	5			
1988			6	8	10	10	8	9							
1989															
1990															
	1	7	9	9	9	9	9	9	8	8	8	7	0	0	0

NUMBER OF OBSERVATIONS IN EACH 10-DAY PERIOD FOR: MCGRATH

PERIOD->	MAY			JUN			JUL			AUG			SEP		
YEAR	1	11	21	1	11	21	1	11	21	1	11	21	1	11	21
1980		3	10	9	9	10	10	9	10	9	10	8			
1981		3	11	10	10	9	8	9	11	8	6				
1982			7	10	8	7	4	9	9	7	9	7	1		
1983				3		1	8	9	5	5	10	2			
1984			2	10	10	10	10	10	11	10	10	10			
1985						5	10	9	11	10	9	10			
1986	10	9			1										
1987		2	7	10	9	10	10	7	11	9	7	6			
1988			5	9	6	10	8	8							
1989															
1990															
	1	4	6	7	7	8	8	8	7	7	7	6	1	0	0

Exhibit 2

Completeness of Weather Data
1980 to 1988 By 10-Day Periods

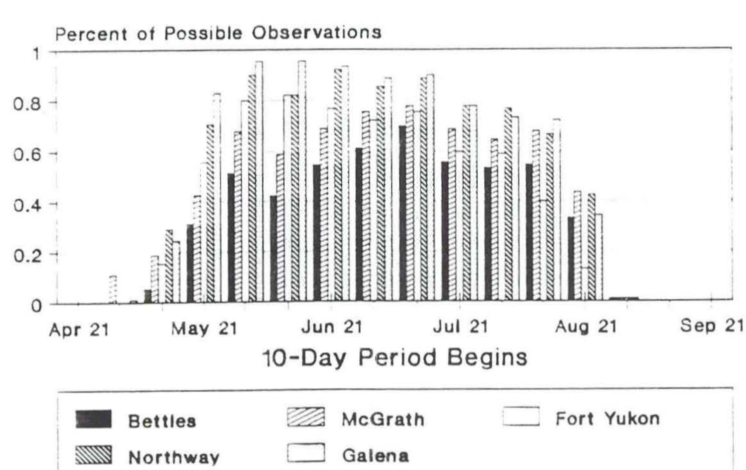


Exhibit 3

Cataloged Weather Data Per 10-day Period, 1955-1990

NUMBER OF VALID OBSERVATIONS IN EACH 10-DAY PERIOD FOR: GALENA

PERIOD->	I--APR---			I--MAY---			I--JUN---			I--JUL---			I--AUG---			I--SEP---		
YEAR	1	11	21	1	11	21	1	11	21	1	11	21	1	11	21	1	11	21
1955	9	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1956	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1957	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1958	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1959	9	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1960	10	9	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1961	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1962	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1963	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1964	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1965	10	10	10	10	10	11	10	10	10	10	10	11	10	10	11	10	10	10
1966						1			1	7	3		1	3	7	1	4	1
1967							1	1	2	4	3	6	3		1			
1968																		
1969																		
1970																		
1971																		
1972																		
1973																		
1974																		
1975						8	6	10	9	9	7	9	6	7	9			
1976			3		1	10	10	10	10	9	10	11	10	10	10	10		
1977			3	9	10	10	10	10	10	9	10	11	10	10	9	8		
1978				3	9	11	10	10	10	10	10	11	10	10	11	10		
1979				3	7	11	10	10	10	9	10	10	9	9	10	8	3	
1980				1	5	10	10	10	9	10	9	10	8	10	4			
1981					5	10	10	10	10	9	10	10	8	5				
1982					2	11	9	8	7	4	7	9	7	10	4			
1983					3	9	10	10	10	10	8	5	6	7	1			
1984						10	10	10	9	10	10	11	10	10	3			
1985					1	9	10	9	9	10	10	10	9	8	10			
1986					4	9	10	10	10	9	9	11	9	8	7			
1987					2	8	9	9	10	10	9	11	9	7	5			
1988						6	8	10	10	8	9							
1989																		
1990																		
N. YRS	11	11	13	15	22	26	26	26	27	27	27	25	26	25	25	16	13	12

Exhibit 4

FIRE OCCURRENCE

Source: Alaska BLM

Scope: Fire Start Location within 100 mile block of weather station

Years: 1980-1988 (Because no weather data, 1989-90)

Season: May 1 through September 30

Attributes: Discovery Date, Final Fire Size, Weather Station Association. No condsideration of suppression/management strategy.

Fire Count by 10-Day Period and Size Class. Zone = Northway (1980-88)

Period	A	B	C	D	E	F	G	ALL	Acres
Apr 21	2	0	1	0	0	0	0	3	25.1
May 01	2	1	1	1	0	0	0	5	154.0
May 11	3	3	1	0	0	0	0	7	31.0
May 21	6	1	0	0	0	0	0	7	1.3
Jun 01	3	1	0	0	0	0	0	4	2.1
Jun 11	4	4	0	0	0	2	0	10	2608.0
Jun 21	4	6	0	0	1	0	1	12	31842.0
Jul 01	7	4	3	0	0	1	0	15	1447.5
Jul 11	2	0	0	0	0	0	0	2	0.1
Jul 21	2	1	0	0	0	0	0	3	8.1
Aug 11	2	3	1	0	0	0	0	6	54.3
Aug 21	4	1	0	0	0	0	0	5	4.1
Sep 01	4	6	0	0	0	0	0	10	9.5
Sep 11	2	3	0	0	0	0	0	5	1.3
Sep 21	1	0	0	0	0	0	0	1	0.0
Totals	48	34	7	1	1	3	1	95	36188.4

Fire Count by 10-Day Period and Size Class. Zone = Fort Yukon (1980-88)

Period	A	B	C	D	E	F	G	ALL	Acres
May 01	0	1	0	0	0	0	0	1	1.0
May 11	0	4	2	0	0	0	0	6	49.0
May 21	3	7	1	0	1	0	0	12	697.0
Jun 01	2	4	2	0	0	0	0	8	38.1
Jun 11	2	6	3	1	0	2	1	15	110815.1
Jun 21	4	9	1	0	0	3	3	20	468969.2
Jul 01	11	10	0	0	1	0	2	24	37543.6
Jul 11	2	5	1	1	0	1	4	14	69184.7
Jul 21	3	4	0	0	0	0	0	7	11.3
Aug 01	4	5	0	1	0	0	1	11	88953.7
Aug 11	3	2	0	0	0	0	0	5	1.5
Aug 21	0	1	0	0	0	0	0	1	1.5
Sep 01	0	1	0	0	0	0	0	1	1.0
Sep 11	0	1	0	0	0	0	0	1	1.5
Totals	34	60	10	3	2	6	11	126	776268.3

Exhibit 4 (cont.)

Fire Occurrence (con't)

Fire Count by 10-Day Period and Size Class. Zone = Bettles (1980-88)

Period	A	B	C	D	E	F	G	ALL	Acres
May 11	0	0	1	0	0	0	0	1	60.0
May 21	1	1	0	1	0	0	0	3	126.0
Jun 01	0	1	2	0	0	0	0	3	70.3
Jun 11	15	5	3	0	2	2	1	28	24994.0
Jun 21	17	18	7	2	1	0	0	45	867.4
Jul 01	18	23	7	0	2	0	0	50	1422.9
Jul 11	6	12	3	3	0	1	0	25	2398.9
Jul 21	2	2	2	0	0	0	0	6	82.0
Aug 01	0	0	0	0	0	1	0	1	1000.0
Totals	59	62	25	6	5	4	1	162	31021.5

Fire Count by 10-Day Period and Size Class. Zone = Galena (1980-88)

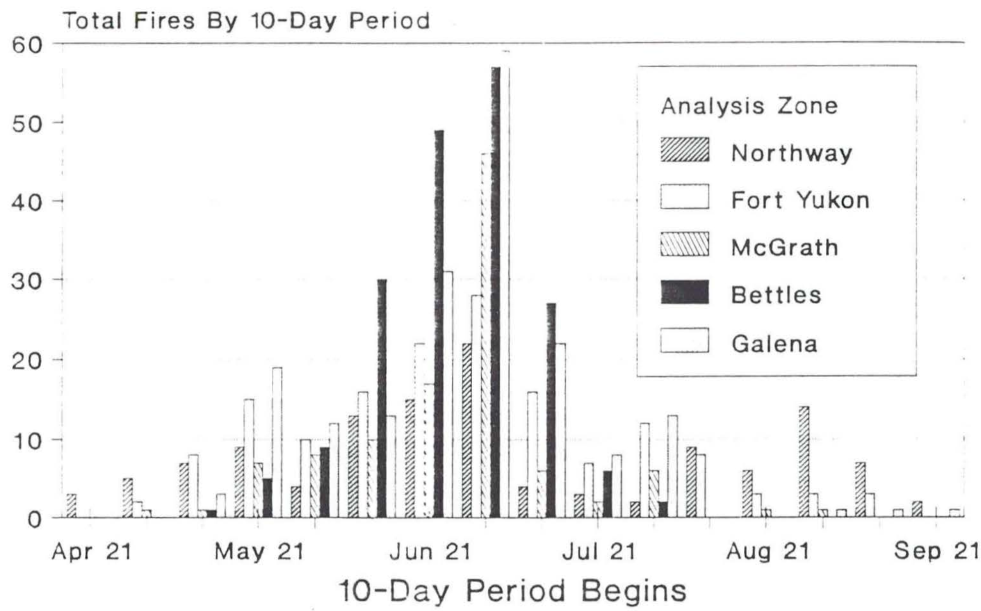
Period	A	B	C	D	E	F	G	ALL	Acres
May 11	0	3	0	0	0	0	0	3	8.0
May 21	5	4	3	0	0	0	0	12	104.3
Jun 01	4	4	2	1	0	0	1	12	12070.0
Jun 11	5	7	0	0	0	0	0	12	18.4
Jun 21	13	11	6	0	1	0	0	31	1060.2
Jul 01	10	21	6	3	3	3	1	47	12166.6
Jul 11	5	10	4	1	0	0	2	22	89829.0
Jul 21	2	4	1	0	0	0	0	7	21.8
Aug 01	1	7	1	0	1	1	0	11	2658.8
Sep 01	0	0	1	0	0	0	0	1	40.0
Sep 11	0	1	0	0	0	0	0	1	5.0
Sep 21	0	0	1	0	0	0	0	1	25.0
Totals	45	72	25	5	5	4	4	160	118007.1

Fire Count by 10-Day Period and Size Class. Zone = McGrath (1980-88)

Period	A	B	C	D	E	F	G	ALL	Acres
Mar 01	0	0	0	1	0	0	0	1	200.0
May 01	0	0	1	0	0	0	0	1	25.0
May 11	0	1	0	0	0	0	0	1	2.0
May 21	2	4	1	0	0	0	0	7	22.6
Jun 01	0	4	3	0	0	1	0	8	1096.0
Jun 11	2	4	2	0	0	2	0	10	3420.0
Jun 21	1	12	1	0	0	0	0	14	82.0
Jul 01	5	13	3	1	4	6	1	33	16668.1
Jul 11	2	2	0	0	0	0	2	6	115106.0
Jul 21	0	0	0	0	0	0	1	1	5000.0
Aug 01	1	1	0	0	1	1	1	5	10702.0
Sep 01	1	0	0	0	0	0	0	1	0.0
Totals	14	41	11	2	5	10	5	88	152323.7

Exhibit 5

Fires By Analysis Zone
1980-1988



Fire Size Classes
1980-1988

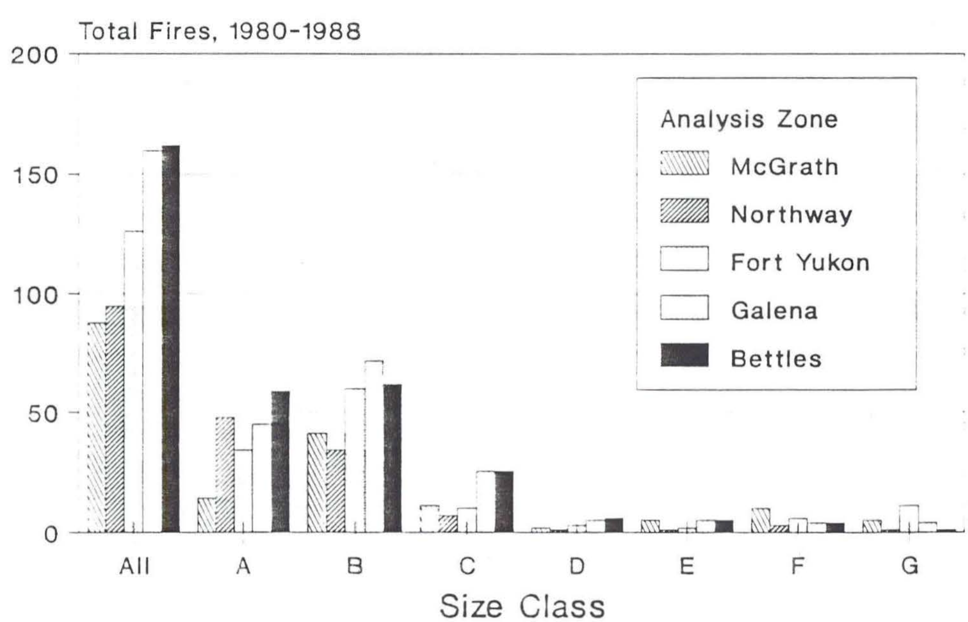
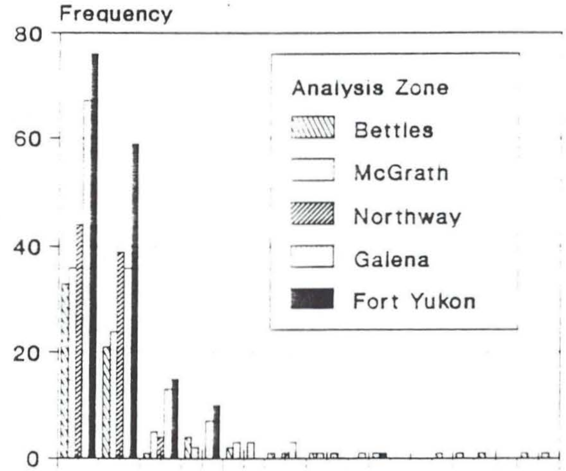


Exhibit 6

Fires Per Fire Day
1980-1988



	1+	1	2	3	4	5	6	7	8	9	10	11
Bettles	33	21	1	4	2	1	1			1	1	1
McGrath	36	24	5	2	3		1	1				
Northway	44	39	4			1						
Galena	67	36	13	7	3	3	1	1		1		1
Fort Yukon	76	59	15	10				1				

Fires Per Fire Day

Exhibit 7

U.S.

NFDRS System Structure

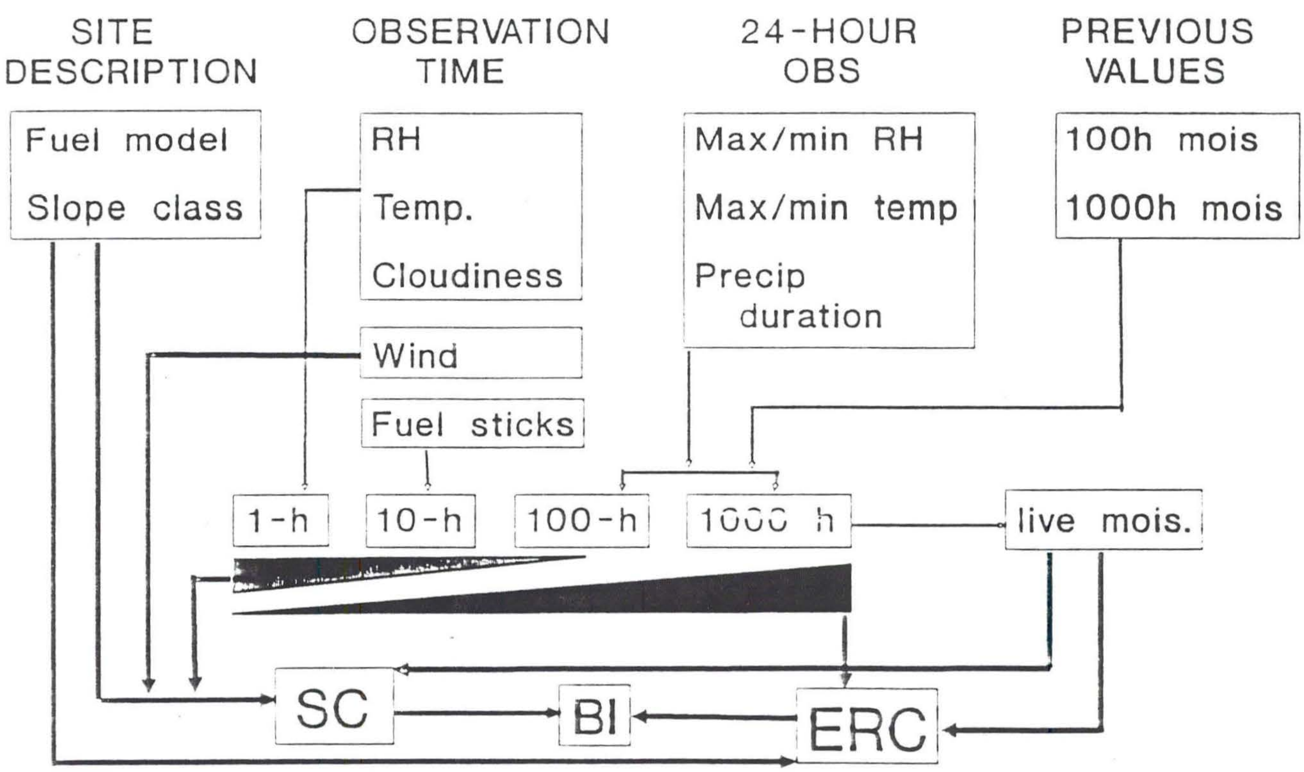
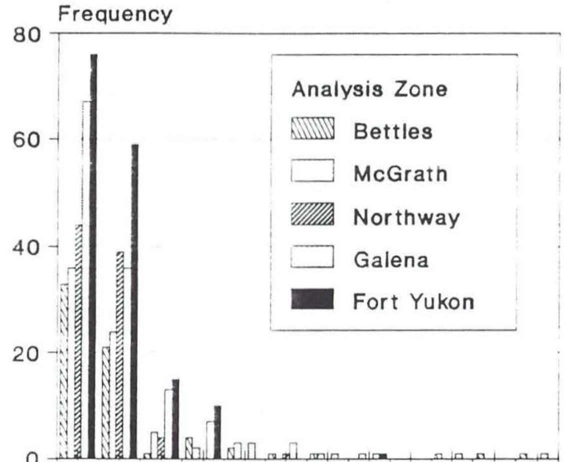


Exhibit 6

Fires Per Fire Day
1980-1988

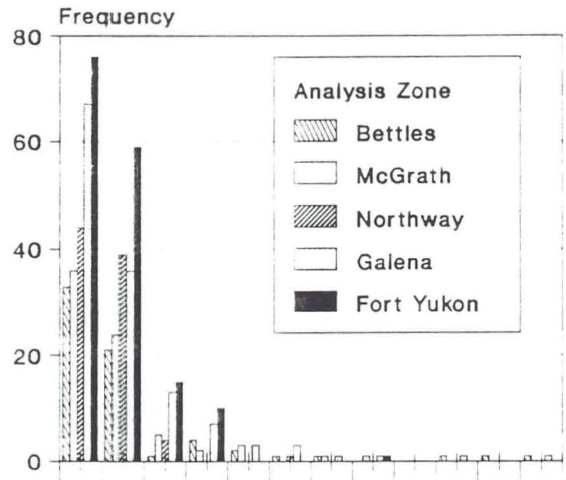


	1+	1	2	3	4	5	6	7	8	9	10	11
Bettles	33	21	1	4	2	1	1			1	1	1
McGrath	36	24	5	2	3		1	1				
Northway	44	39	4			1						
Galena	67	36	13	7	3	3	1	1		1		1
Fort Yukon	76	59	15	10				1				

Fires Per Fire Day

Exhibit 6

Fires Per Fire Day
1980-1988



	1+	1	2	3	4	5	6	7	8	9	10	11
Bettles	33	21	1	4	2	1	1			1	1	1
McGrath	36	24	5	2	3		1	1				
Northway	44	39	4			1						
Galena	67	36	13	7	3	3	1	1		1		1
Fort Yukon	76	59	15	10				1				

Fires Per Fire Day

Exhibit 7

U.S.

NFDRS System Structure

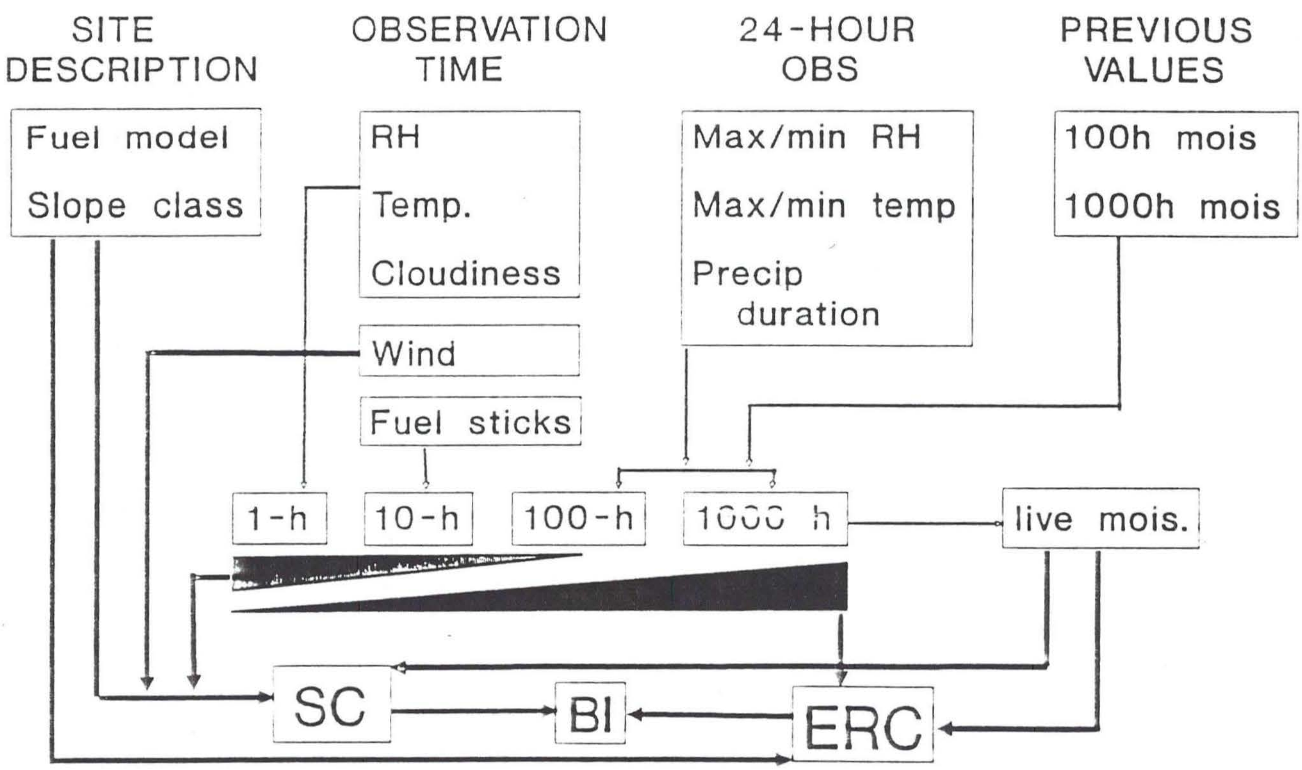


Exhibit 8

CCFDRS

Canadian Forest Fire Danger Rating System

BLOCK DIAGRAM OF THE FIRE WEATHER INDEX SYSTEM

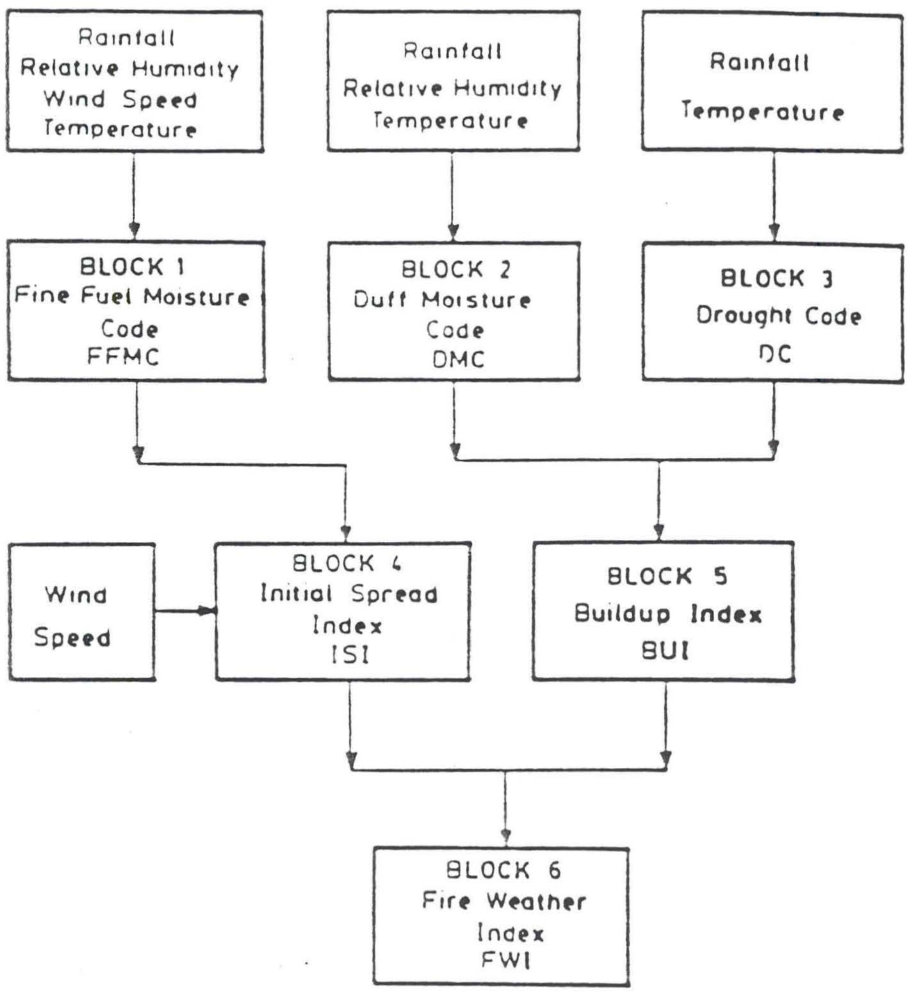


Exhibit 9

Table 5.—List of fuel models in the 1978 NFDRS (Models A-E, G-I were included in 1972 NFDRS; model F represents a different fuel than in 1972 NFDRS)

Fuel model	General description
A	Western annual grasses
B	California mixed chaparral
C	Pine grass savanna
D	Southern rough
E	Hardwoods (winter)
F	Intermediate brush
* G	Short needle pine (heavy dead)
H	Short needle pine (normal dead)
I	Heavy logging slash
J	Intermediate logging slash
K	Light logging slash
* L	Western perennial grass
N	Sawgrass
O	High pocosin
P	Southern pine plantation
* Q	Alaskan black spruce
* R	Hardwoods (summer)
* S	Tundra
T	Sagebrush-grass
U	Western long-needled conifer

Table 14.—Physical attributes of each of the fuel models on the 1978 National Fire-Danger Rating System

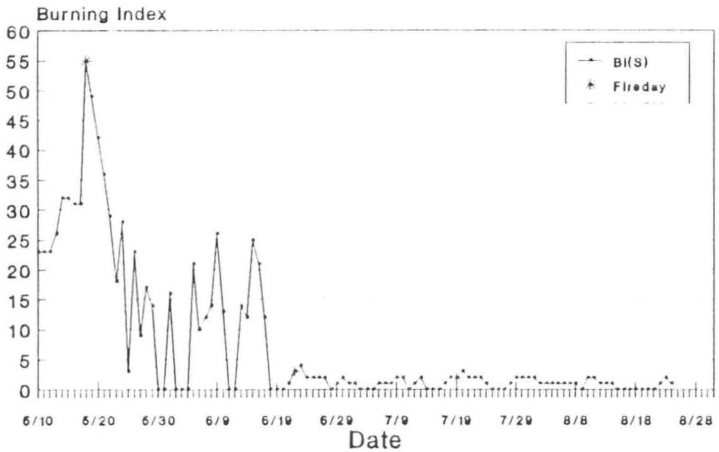
Attribute	A	B	C	D	E	F	G	H	I	J	K	L	N	O	P	Q	R	S	T	U
	Fuel Model																			
Load (tons/acre)																				
1-hour dead	0.2	3.5	0.4	2.0	1.5	2.5	2.5	1.5	12.0	7.0	2.5	0.25	1.5	2.0	1.0	2.0	0.5	0.5	1.0	1.5
10-hour dead	—	4.0	1.0	.5	2.0	2.0	2.0	1.0	12.0	7.0	2.5	—	1.5	3.0	1.0	2.5	.5	.5	.5	1.5
100-hour dead	—	.5	—	—	.25	1.5	5.0	2.0	10.0	6.0	2.0	—	—	3.0	.5	2.0	.5	.5	—	1.0
1.000-hour dead	—	—	—	—	—	—	12.0 ✓	2.0	12.0	5.5	2.5	—	—	2.0	—	1.0	—	.5	—	—
Woody	—	11.5	.5	3.0	.5	9.0	.5	.5	—	—	—	—	2.0	7.0	.5	4.0	.5	.5	2.5	.5
Herbaceous	.3	—	.8	.75	.5	—	.5	.5	—	—	—	.5	—	—	.5	.5	.5	.5	.5	.5
Surface-area-to-volume ratio (1/ft)																				
1-hour dead	3.000	700	2.000	1.250	2.000	700	2.000	2.000	1.500	1.500	1.500	2.000	1.600	1.500	1.750	1.500	1.500	2.500	2.500	1.750
10-hour dead	—	109	109	109	109	109	109	109	109	109	109	—	109	109	109	109	109	109	109	109
100-hour dead	—	30	—	—	30	30	30	30	30	30	30	—	—	30	30	30	30	30	—	30
1.000-hour dead	—	8	—	—	—	—	8	8	8	8	8	—	—	8	—	8	—	8	—	—
Woody	—	1.250	1.500	1.500	1.500	1.250	1.500	1.500	—	—	—	—	1.500	1.500	1.500	1.200	1.500	1.200	1.500	1.500
Herbaceous	3.000	—	2.500	1.500	2.000	—	2.000	2.000	—	—	—	2.000	—	—	2.000	1.500	2.000	1.500	2.000	2.000
Heat content (all fuels)																				
(Btu/lb)	8.000	9.500	8.000	9.000	8.000	9.500	8.000	8.000	8.000	8.000	8.000	8.000	8.700	9.000	8.000	8.000	8.000	8.000	8.000	8.000
Moisture of extinction (%)																				
Dead	15	15	20	30	25	15	25	20	25	25	25	15	25	30	30	25	25	25	15	20
Fuel bed depth (ft)	.8	4.5	.75	2.0	.4	4.5	1.0	.3	2.0	1.3	.6	1.0	3.0	4.0	.4	3.0	.25	.4	1.25	.5
SC_{max}	301	58	32	68	25	24	30	8	65	44	23	178	167	99	14	59	6	17	96	16

Constant fuel particle values for all fuels:

Fuel particle density (ρ_p):	32 lb/ft³
Total mineral content (S_T):	0.0555
Effective mineral content (S_e):	0.01

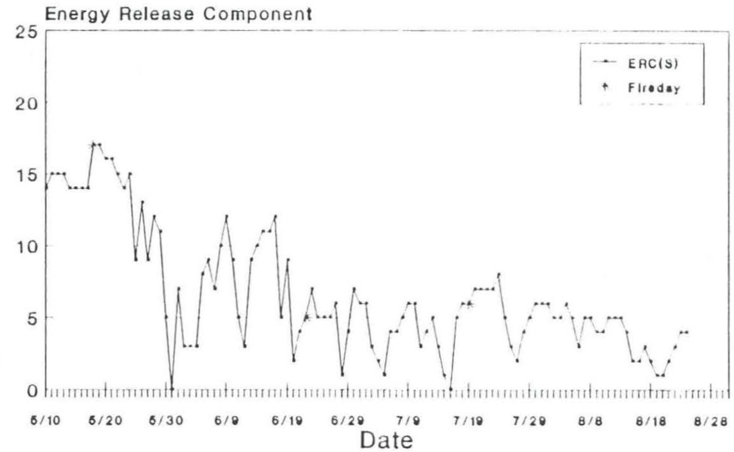
Galena Zone - 1980

BI - Fuel Model L



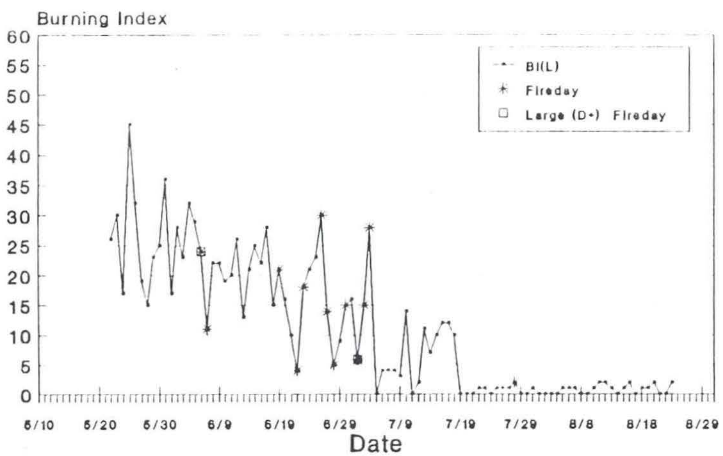
Galena Zone - 1980

ERC - Fuel Model S



Galena Zone - 1984

BI - Fuel Model L



Galena Zone - 1984

ERC - Fuel Model S

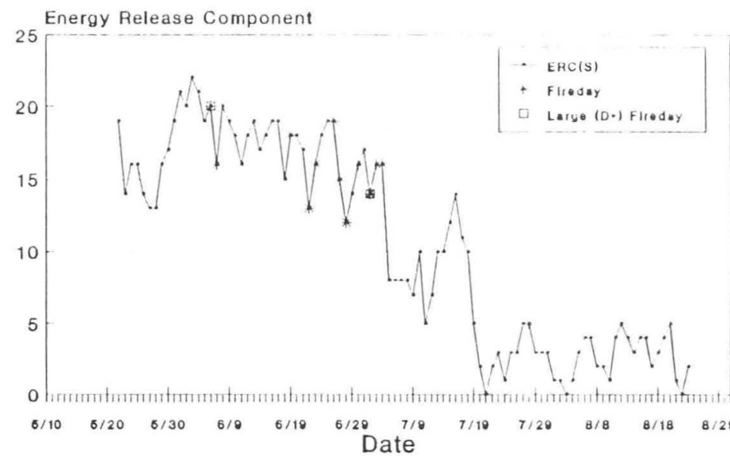
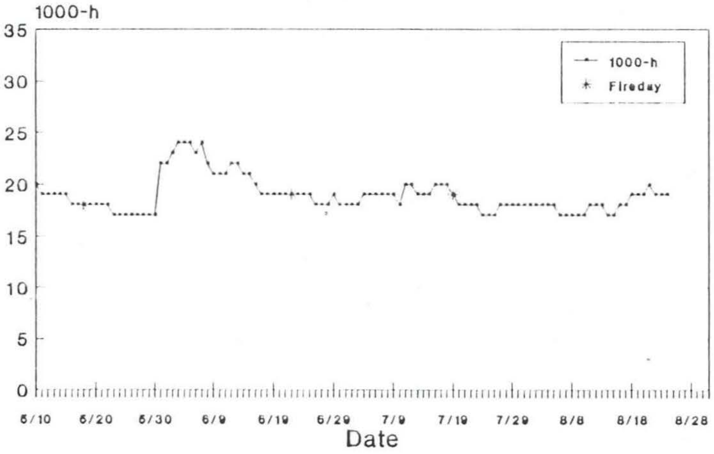


Exhibit 10

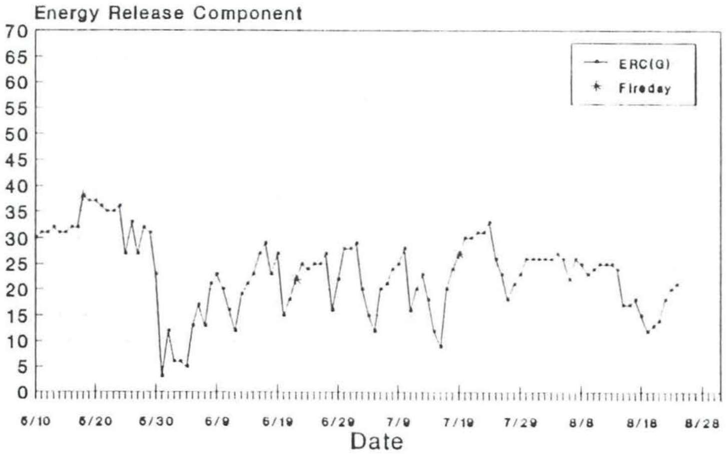
Galena Zone - 1980

1000-h



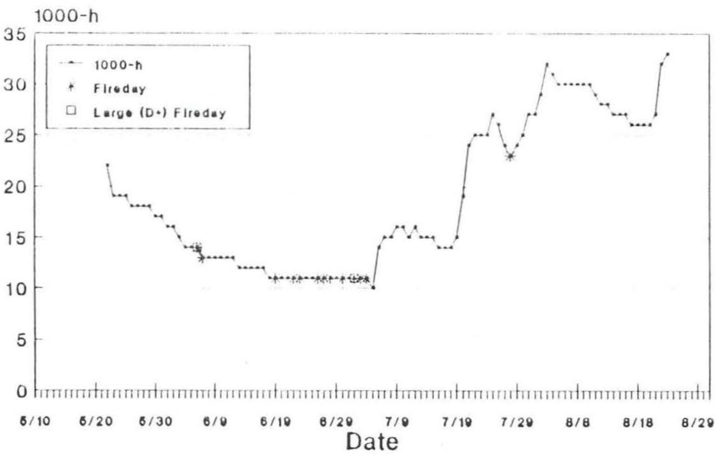
Galena Zone - 1980

ERC - Fuel Model G



Galena Zone - 1984

1000-h



Galena Zone - 1984

ERC - Fuel Model G

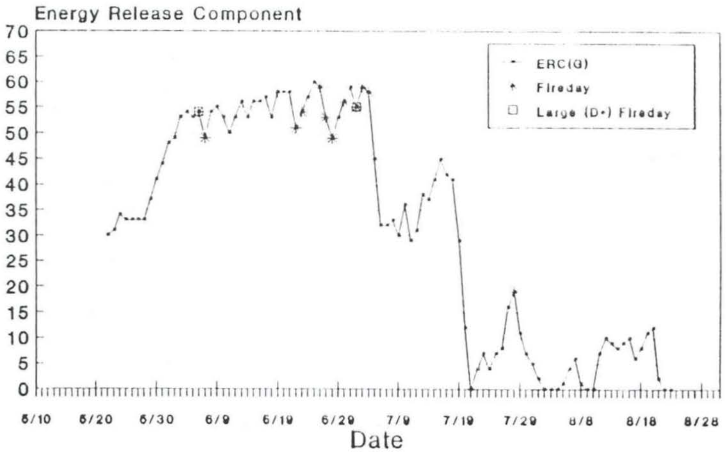


Exhibit 10 (Cont.)

Exhibit 11

Galena - BI(L)

SUMMARY OF "FIREDAY" OCCURRENCE MODELS. FILE: GAL_MODEL_PARMS

MODEL 14: PHAT = 1./(1.+ EXP(-.0198*BI_L + 2.7028))

Percentile NTILE	*BI(L)* ~~*Index*~~ VALUE RANGE	TOTAL DAYS	/---- FIRE DAYS ----/ *Observed* N.	*Observed* FRAC.	*predicted* ~~PHAT~~ *FRAC.*	*predicted* EXP. N.	/-- NO FIRE --/ *DAYS* N.	EXP. N.
20	0- 0	170	1	.01	.06	11	169	159
34	1- 1	116	2	.02	.06	7	114	109
48	2- 2	113	6	.05	.07	7	107	106
53	3- 3	47	8	.17	.07	3	39	44
63	4- 10	85	17	.20	.07	6	68	79
76	11- 17	109	12	.11	.08	9	97	100
90	18- 29	120	14	.12	.10	12	106	108
95	30- 35	39	1	.03	.11	4	38	35
99	36- 49	35	3	.09	.13	5	32	30
100	50- 57	6	1	.17	.16	1	5	5
		840	65			65	775	775

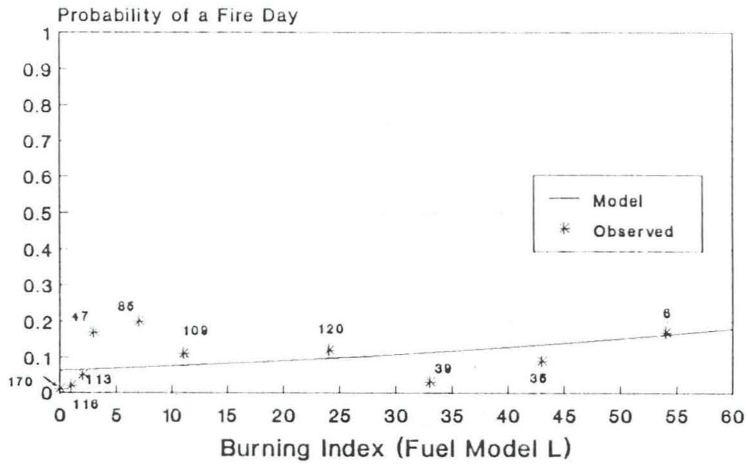
Galena - ERC(G)

SUMMARY OF "FIREDAY" OCCURRENCE MODELS. FILE: GAL_MODEL_G_PARMS

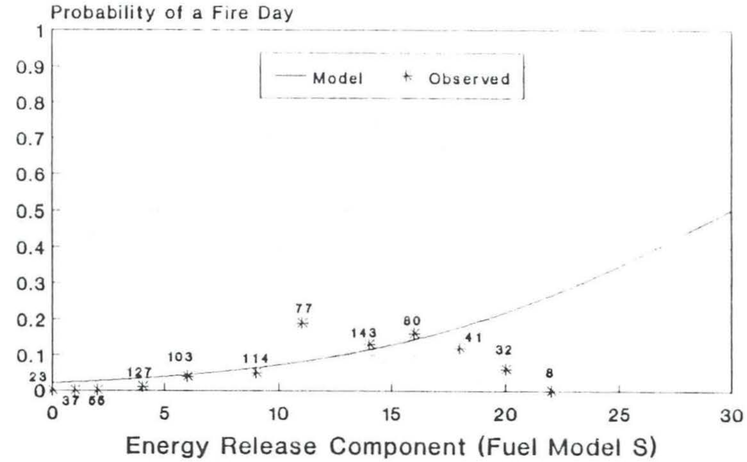
MODEL 3: PHAT = 1./(1.+ EXP(-.0892*ERC_G + 5.5996))

Percentile NTILE	*ERC(G)* VALUE RANGE	TOTAL DAYS	/---- FIRE DAYS ----/ *Observed* N.	*Observed* FRAC.	*Predicted* ~~PHAT~~ *FRAC.*	*Predicted* EXP. N.	/-- NO FIRE --/ *DAYS* *Obs.* N.	*Predicted* EXP. N.
5	0- 0	44	0	.00	.00	0	44	44
11	1- 6	48	0	.00	.01	0	48	48
26	7- 17	127	0	.00	.01	1	127	126
38	18- 23	96	4	.04	.02	2	92	94
52	24- 30	119	4	.03	.04	5	115	114
63	31- 34	98	4	.04	.06	6	94	92
77	35- 39	112	16	.14	.09	10	96	102
91	40- 46	118	17	.14	.15	17	101	101
96	47- 53	46	10	.22	.24	11	36	35
99	54- 58	27	8	.30	.35	10	19	17
100	59- 60	5	2	.40	.43	2	3	3
		840	65			64	775	776

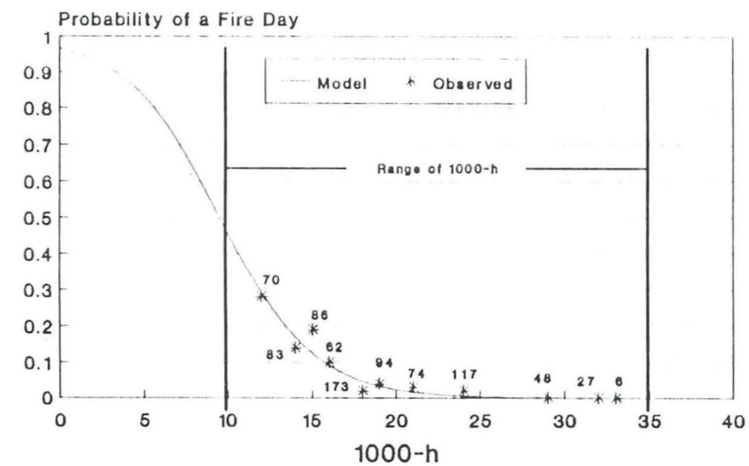
Galena Probability Curve 1980-1988



Galena Probability Curve 1980-1988



Galena Probability Curve 1980-1988



Galena Probability Curve 1980-1988

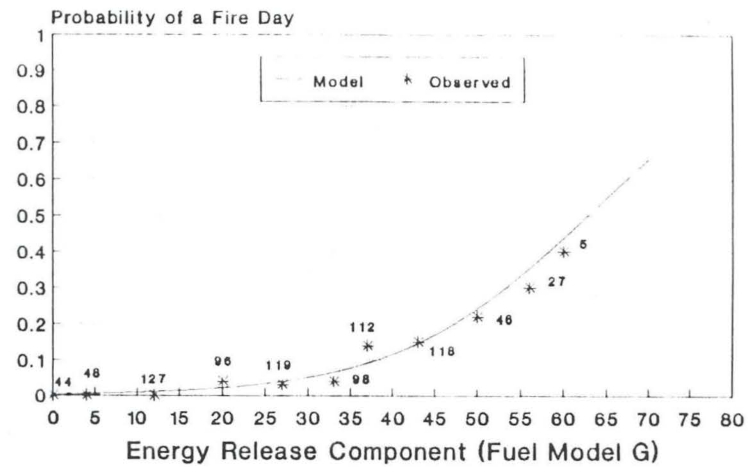
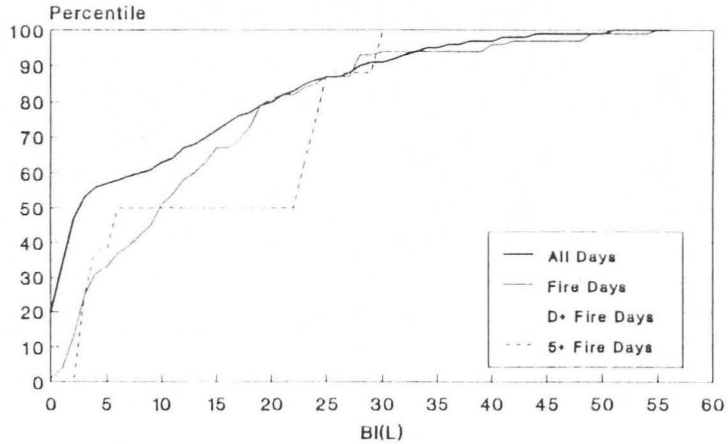


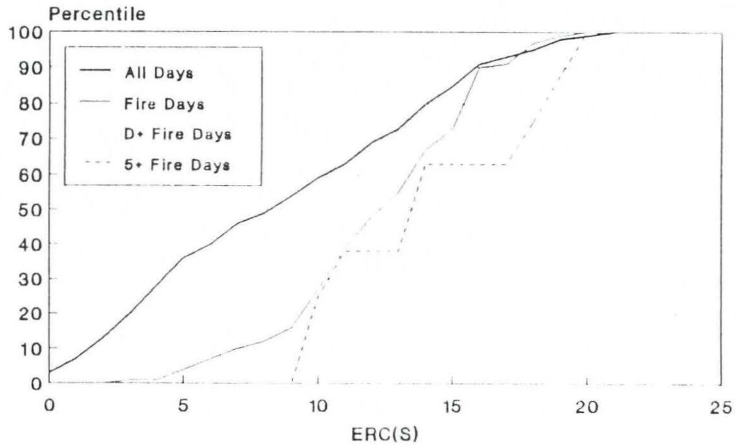
Exhibit 12

Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



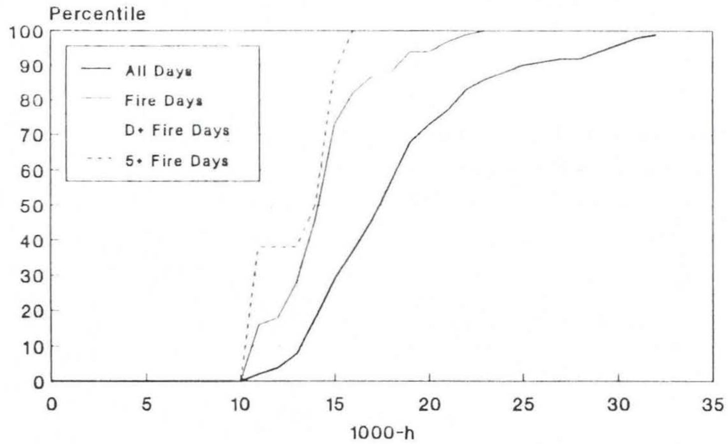
1980-1988

Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



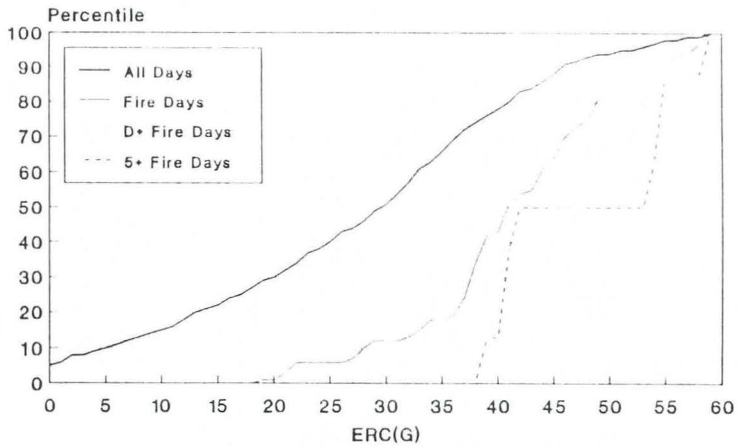
1980-1988

Galena Zone
Cumulative Distributions For
All, Fire, Large, & Multiple Fireday



1980-1988

Galena Zone
Cumulative Distributions for
All, Fire, Large, & Multi Fire Days

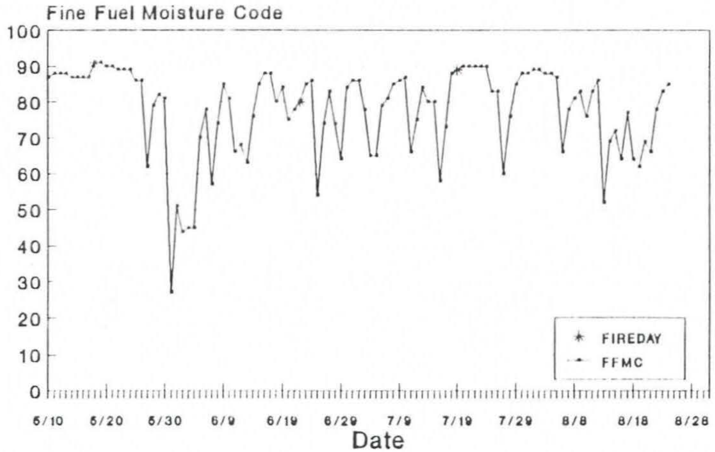


1980-1988

Exhibit 12

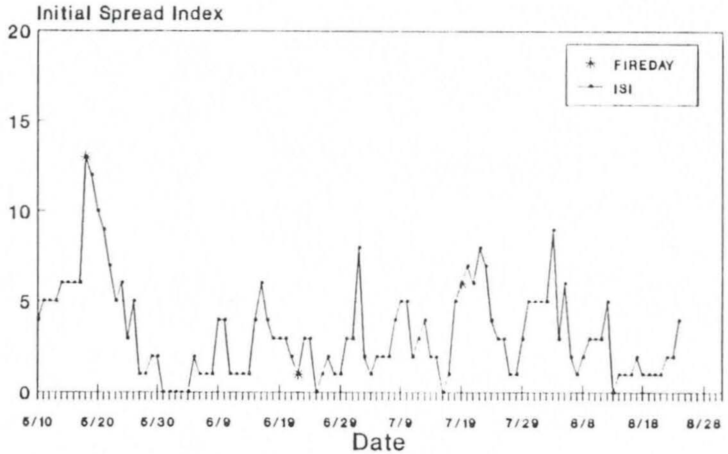
Galena Zone - 1980

FFMC



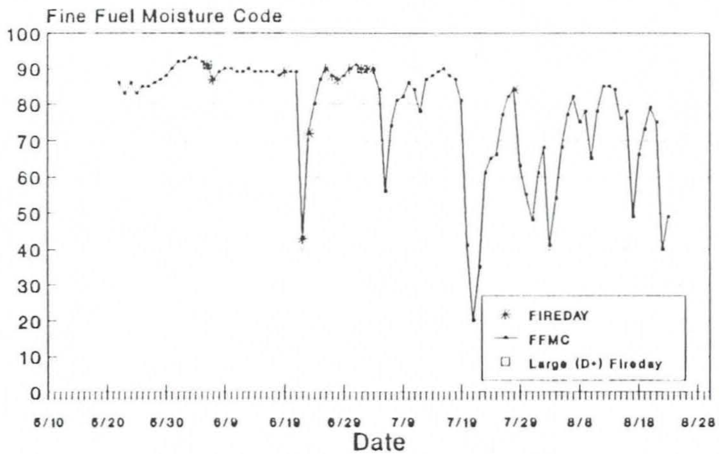
Galena Zone - 1980

ISI



Galena Zone - 1984

FFMC



Galena Zone - 1984

ISI

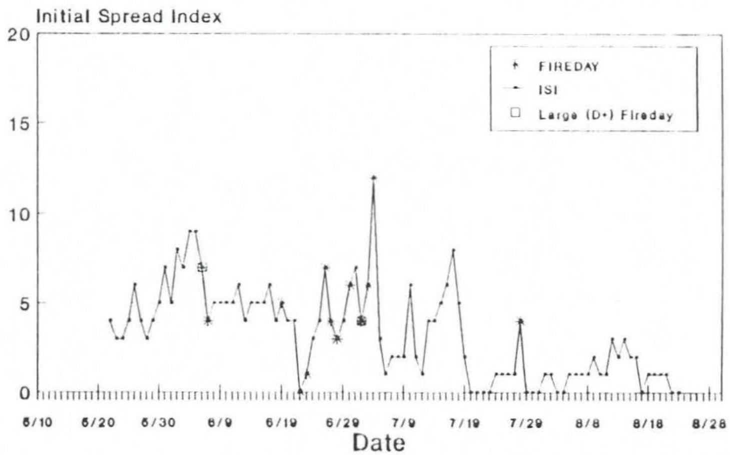
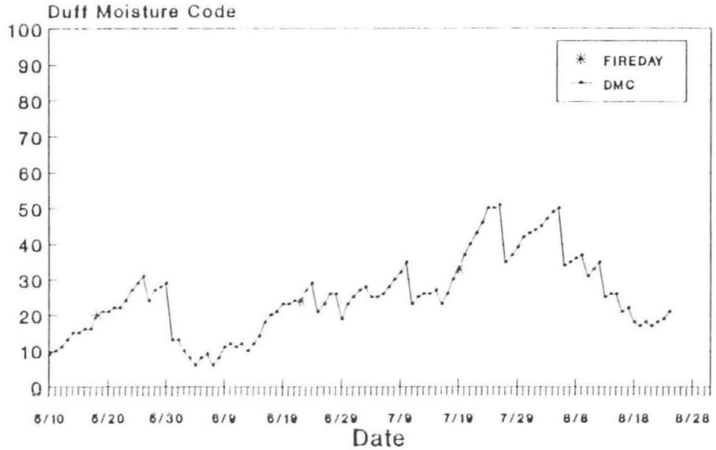


Exhibit 14

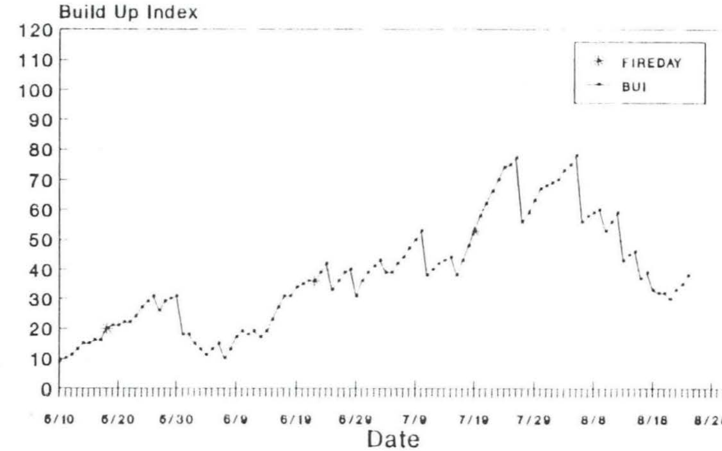
Galena Zone - 1980

DMC



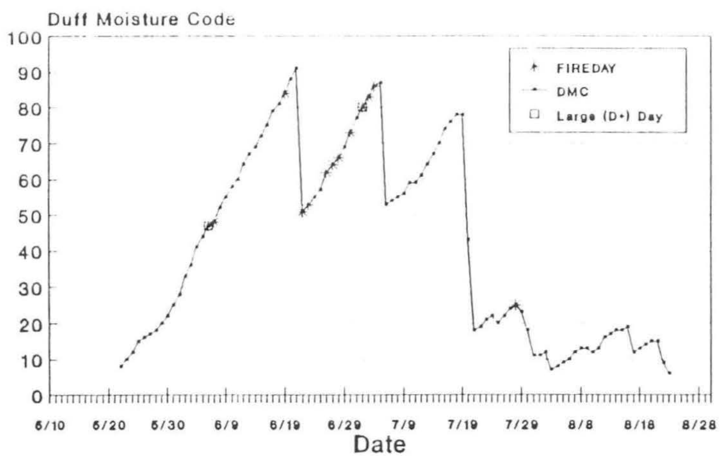
Galena Zone - 1980

BUI



Galena Zone - 1984

DMC



Galena Zone - 1984

BUI

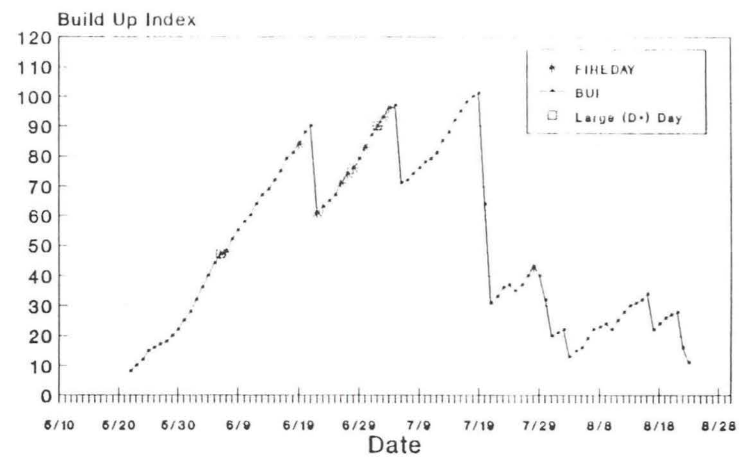
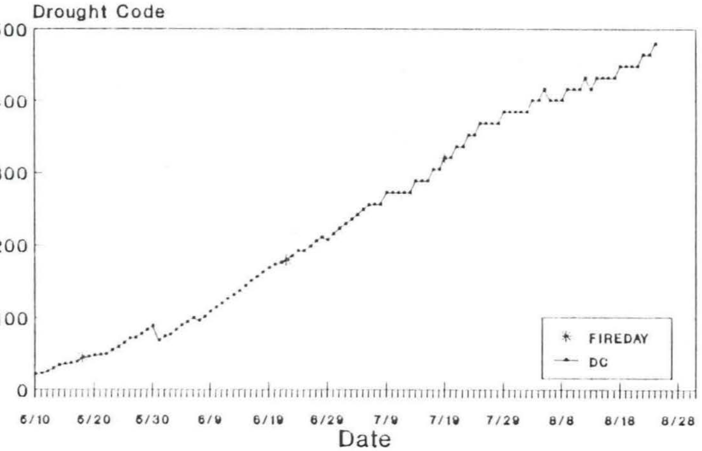


Exhibit 14 (cont)

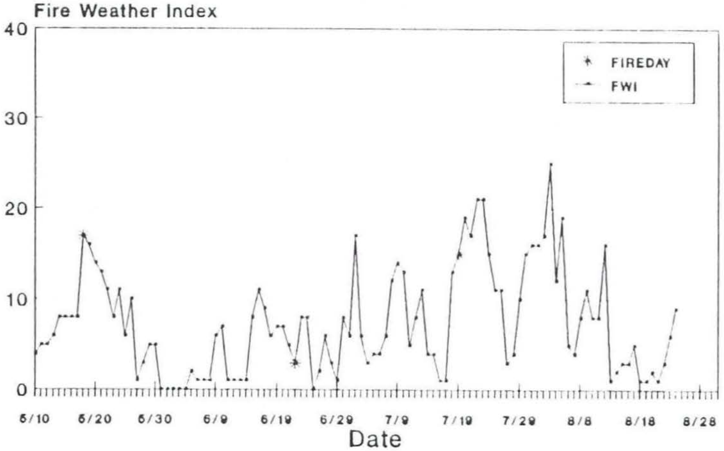
Galena Zone - 1980

DC



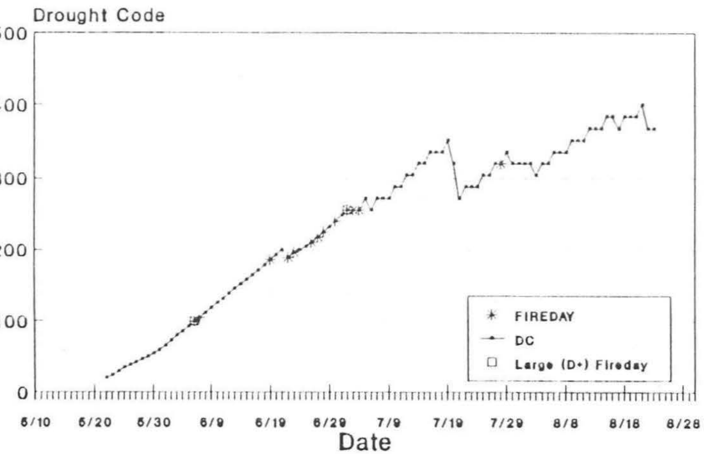
Galena Zone - 1980

FWI



Galena Zone - 1984

DC



Galena Zone - 1984

FWI

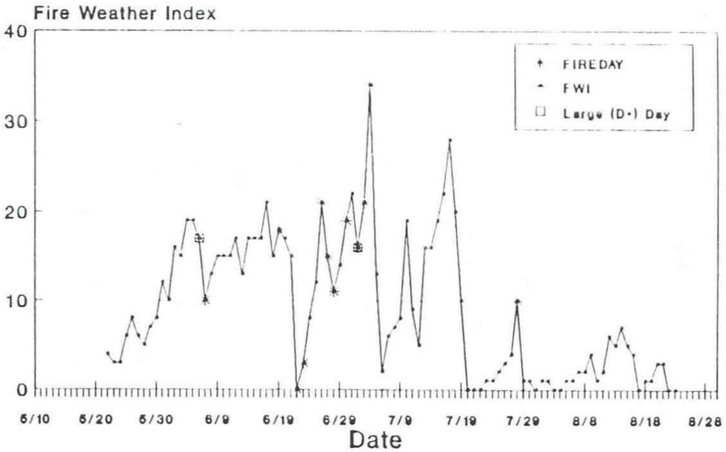
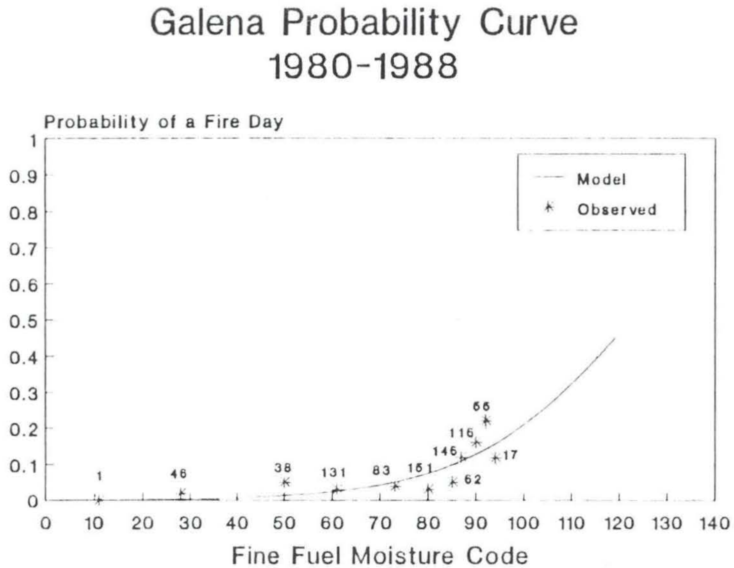
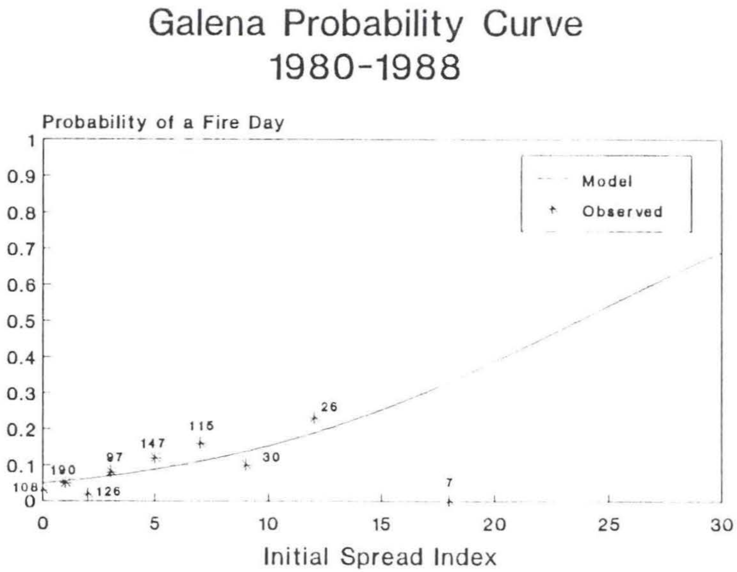
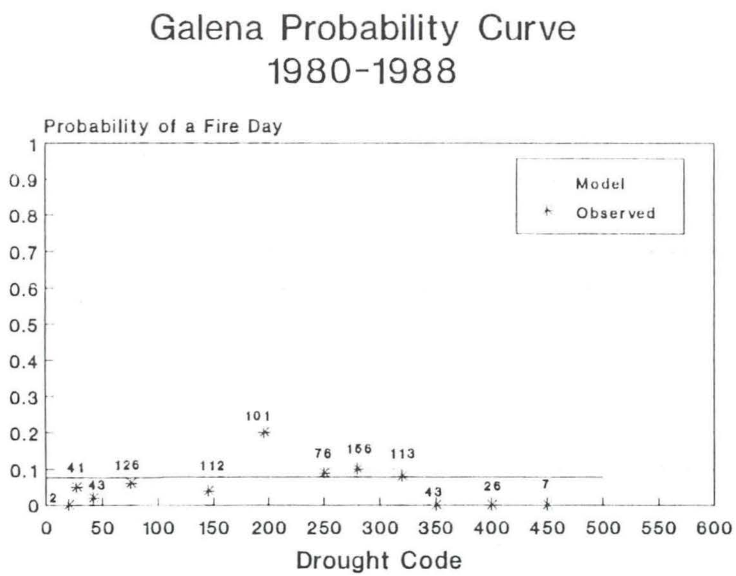


Exhibit 14 (Cont)


Galena Probability Curve
1980-1988
Probability of a Fire Day
Model
Observed
Fine Fuel Moisture Code


Galena Probability Curve
1980-1988
Probability of a Fire Day
Model
Observed
Initial Spread Index


Galena Probability Curve
1980-1988
Probability of a Fire Day
Model
Observed
Drought Code

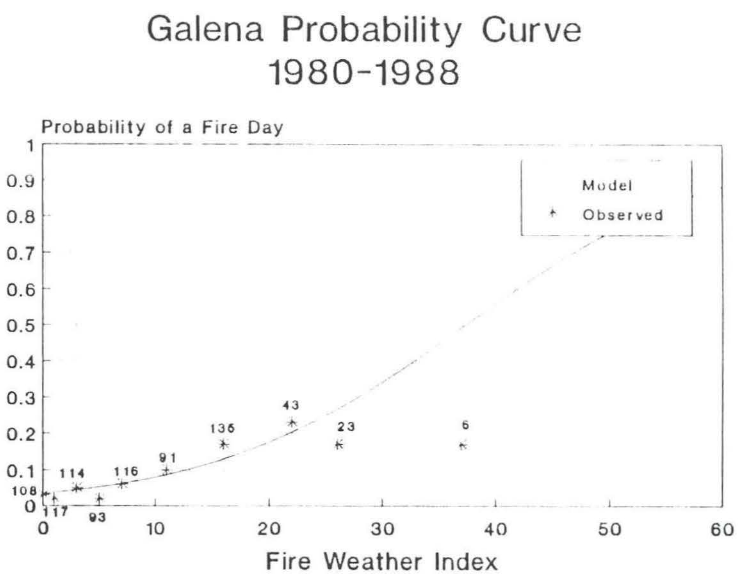
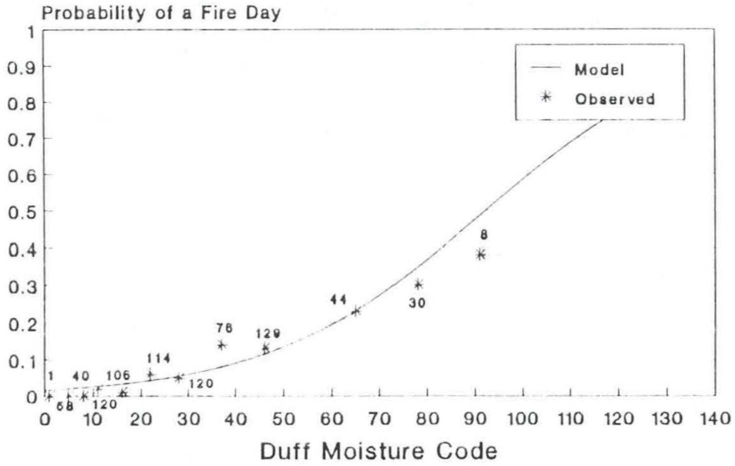

Galena Probability Curve
1980-1988
Probability of a Fire Day
Model
Observed
Fire Weather Index

Exhibit 15

Galena Probability Curve
1980-1988



Galena Probability Curve
1980-1988

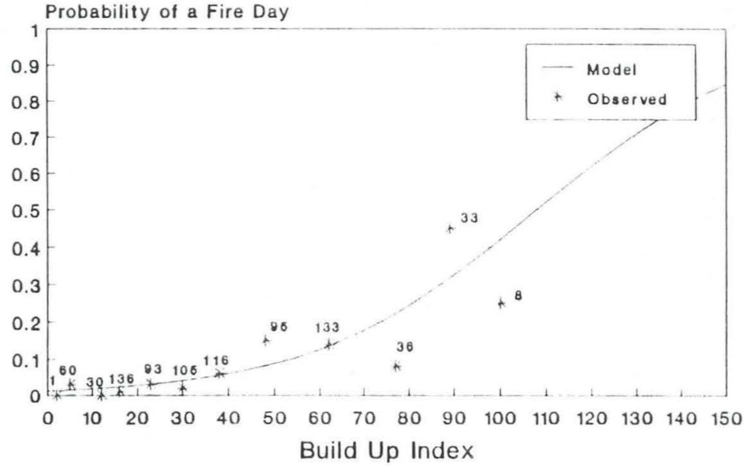
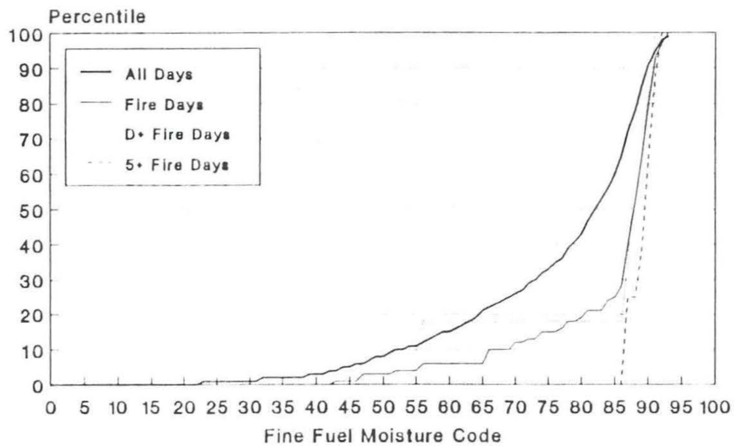


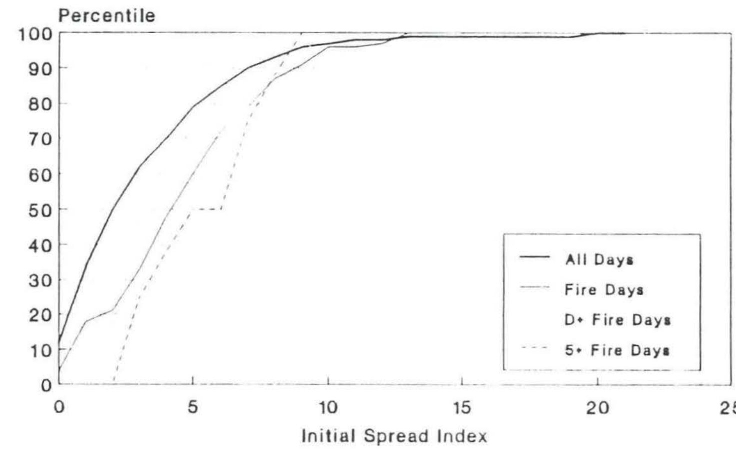
Exhibit 15 (Cont)

Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



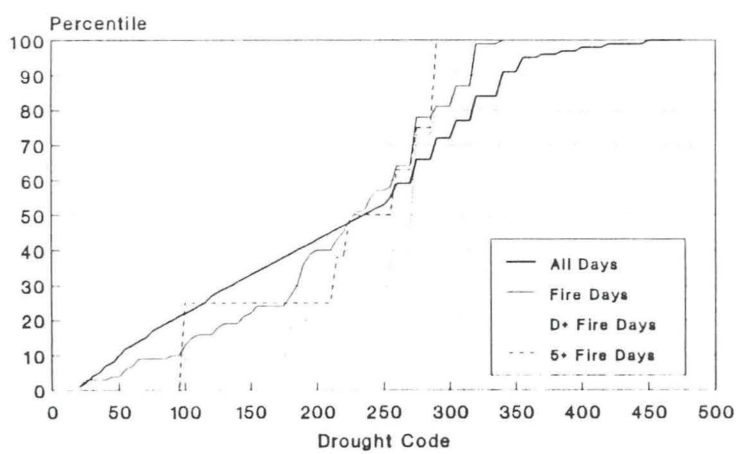
1980-1988

Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



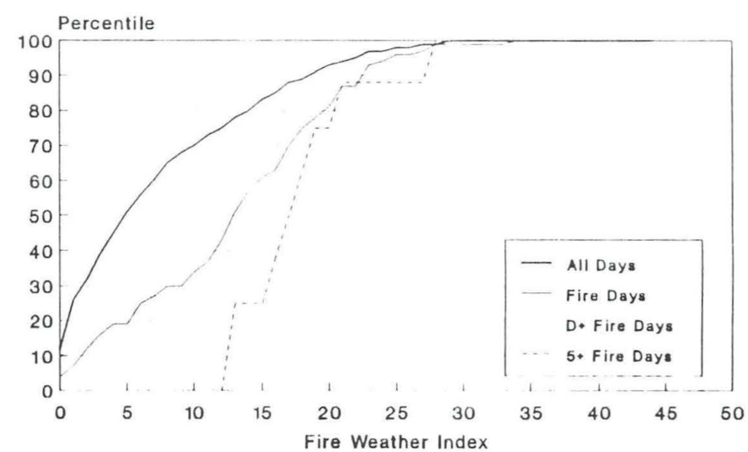
1980-1988

Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



1980-1988

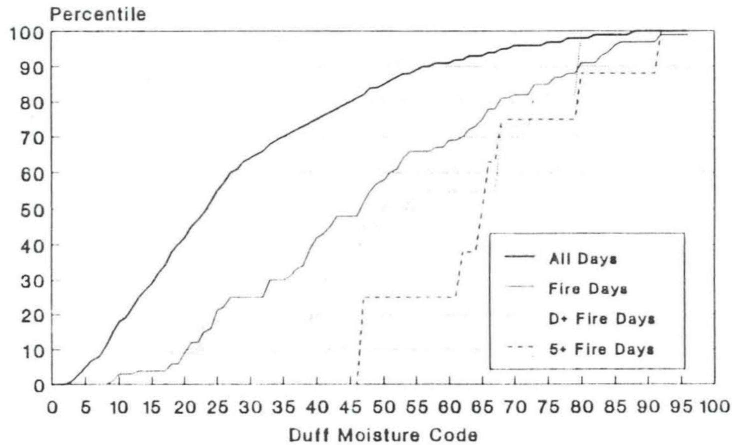
Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



1980-1988

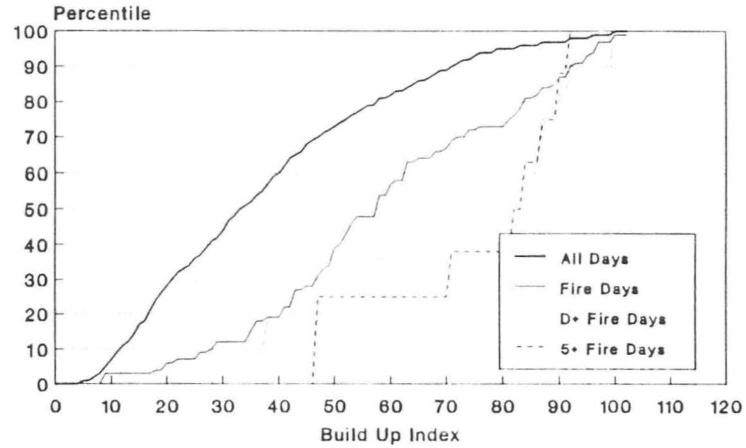
Exhibit 16

Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



1980-1988

Galena Zone
Cumulative Distributions of
All, Fire, Large, & Multiple Firedays



1980-1988

Exhibit 16 (Cont)

Exhibit # 17

Galena - DC

SUMMARY OF "FIREDAY" OCCURRENCE MODELS. FILE: GAL_MODEL_PARMS

MODEL 3: PHAT - 1./(1.+ EXP(-.0002*DC + 2.4974))

Percentile NTILE	DC VALUE RANGE	TOTAL DAYS	FIRE DAYS observed N.	FRAC.	FIRE DAYS Predicted ~~PHAT~~ FRAC.	EXP. N.	NO FIRE Days N. Obs.	EXP. N. Pred.
0	19- 19	2	0	.00	.08	0	2	2
5	20- 34	41	2	.05	.08	3	39	38
10	35- 50	43	1	.02	.08	3	42	40
25	51-114	126	8	.06	.08	10	118	116
38	115-175	112	5	.04	.08	9	107	103
50	176-236	101	20	.20	.08	8	81	93
59	237-270	76	7	.09	.08	6	69	70
78	271-304	156	15	.10	.08	13	141	143
91	305-336	113	9	.08	.08	9	104	104
96	337-368	43	0	.00	.08	3	43	40
99	369-432	26	0	.00	.08	2	26	24
100	433-480	7	0	.00	.08	1	7	6
		846	67			67	779	779

Galena - DMC

SUMMARY OF "FIREDAY" OCCURRENCE MODELS. FILE: GAL_MODEL_PARMS

MODEL 2: PHAT - 1./(1.+ EXP(-.0441*DMC + 4.0689))

Percentile NTILE	DMC VALUE RANGE	TOTAL DAYS	FIRE DAYS observed N.	FRAC.	FIRE DAYS predicted ~~PHAT~~ FRAC	EXP. N.	NO FIRE Days N. Obs.	EXP. N. pred.
0	1- 1	1	0	.00	.02	0	1	1
7	2- 6	58	0	.00	.02	1	58	57
12	7- 8	40	0	.00	.02	1	40	39
26	9- 13	120	3	.02	.03	3	117	117
38	14- 18	106	1	.01	.03	4	105	102
52	19- 24	114	7	.06	.04	5	107	109
66	25- 32	120	6	.05	.06	7	114	113
75	33- 40	76	11	.14	.08	6	65	70
90	41- 58	129	17	.13	.13	17	112	112
96	59- 70	44	10	.23	.23	10	34	34
99	71- 85	30	9	.30	.35	10	21	20
100	86- 97	8	3	.38	.49	4	5	4
		846	67			68	779	778

Appendix B

Research Proposal to United States Department of Interior

RESEARCH PROPOSAL

Project Title:	Determination of Optimum Fire Danger Planning Index (FIRES: Fire Information Retrieval and Evaluation System)
Submitted to:	Interior Fire Coordinating Committee Research Working Team
Submitted by:	Fire Behavior Research Work Unit Intermountain Research Station Missoula, MT
Support Requested:	$164,000.
Starting Date:	April 1, 1992
Duration:	30 months

_______________________ _________
Patricia L. Andrews Date
Principal Investigator

_______________________ _________
Richard C. Rothermel Date
Project Leader

INTRODUCTION

OBJECTIVES

As stated in the attached Statement of Work provided by the DOI for this proposal, the goal and the purpose of this study are as follows:

> The goal of this research is to provide improved assessment of fire danger for better wildland management decisions, improve the choice of prescribed fire decision elements, and enhance economic analyses that serve funding and staffing allocation computations.
>
> The purpose of this project is to select from currently collected and computed indexes and components of fire danger rating, those that most successfully explain the variations experienced in fire business, such as fire occurrence, multiple occurrence days, and days where fires grow rapidly.

Specific objectives of the study are

1. Complete development of an interactive PC program designed for fire managers. We will call it the Fire Information Retrieval and Information System (FIRES).

2. Publish papers documenting specific applications of the methods.

3. Publish a user's manual for the FIRES program.

4. Develop a training package for the FIRES program.

5. Adapt the program for "batch" runs in order to do an analysis of the whole U.S.

6. Divide the U.S. into analysis zones based on climate and fuel. Do a fire danger/fire business analysis for each analysis area. The analysis requires a national, interagency fire data base.

7. Support the development of a national, interagency fire data base.

BACKGROUND

A study on using logistic regression to examine the relationship between fire danger rating values and fire business has proved very successful. A computer program based on these methods will be an aid to application of the current NFDRS and also will be an important part of the future integrated fire management system that will be developed.

The Fire Behavior Research Work Unit (INT-4401) has the assigned responsibility for developing an integrated fire behavior/fire danger rating system. This is one of nine initiatives developed by the Director of Fire and Atmospheric Sciences Research in the Washington Office. The initiative states: "A single,

integrated system that can accommodate the full continuum of spatial/temporal resolution requirements--from National, long-range fire severity forecasting to real-time suppression strategy decisions on actual fires--is needed to meet the varying fire behavior information needs of wildland fire managers."

Problem #2 of the 4 problems outlined in the 5-year RWU 4401 description is as follows:

> The use of two systems for assessing fire potential, i.e. National Fire Danger Rating System (NFDRS) and the Fire Behavior Prediction System (FBPS), with their separate sets of fuel models, causes difficulty when fire management activities make the transition from pre-fire planning to real-time operation.

The first of five elements under this problem is system design.

> A fire analysis system will be designed that will provide increasing information about the fire environment, fire potential, and fire behavior as the fire management need increases from broad assessments, to prefire planning, to specific fire prediction. ...

Work on using logistic regression to analyze the relationship between NFDRS indexes and fire history was conducted under agreements with Systems for Environmental Management: Loftsgaarden and Andrews (INT-88296-COA) and Bradshaw and Andrews (INT-88343-COA). The results of those studies are documented in the final reports for those agreements, and two technical papers are being prepared for publication.

Presentations on the methods and example applications have been given at national, interagency training courses at NARTC and at various fire management meetings. The feedback from fire managers on the utility of the analysis has been very positive.

Methods have been applied successfully to fire and weather/index data from Montana, Mississippi, and California-- areas with very different climate, fuel, and fire business. In addition, the methods were used to compare the U.S. and the Canadian fire danger rating systems in Alaska. An office report is attached. Additional work will be done on that analysis with more complete fire and weather data bases.

The programs that were used as part of the research study are not the type that are appropriate for use by fire managers. We used the IFSL Data General computer and SAS statistical software. Graphics were done using Lotus and Harvard Graphics on a PC. We are now developing a program for PC that includes only necessary options and will not require the purchase of special statistical or graphics software.

One of the programs developed for this study has been adopted as a national system and is now supported by the Forest Service Fire and Aviation Management Washington Office. FCFAST (Bradshaw and Andrews 1991) is used to access fire-related databases and programs stored at the Fort Collins Computer Center (FCCC). It is available in a Data General version for Forest Service users and also in a PC version. Currently all computer resources from FCCC are being converted to the computer center at Kansas City, Missouri. FCFAST is being

updated (to KCFAST) to perform the same functions on a new, integrated fire weather and fire occurrence database at KCCC. The current database contains weather for all federal and state fire management agencies, but only fire occurrence data for fires occurring on Forest Service administered lands.

SCOPE AND METHODS

Statistical Methods

Most of the statistical methods have been developed and tested. Some aspects changed as the study progressed. Loftsgaarden and Andrews are defining the changes that Bradshaw will incorporate into the program.

The statistical software package SAS was used in the initial research study. The final PC program will, however, not require the user to purchase statistical software. At present Bradshaw is programming the mathematics of logistic regression and tests of fit. He is also examining the possibility of purchasing supported and more robust logistic regression software that can be incorporated into his program.

Computer Programs

An interactive program will be developed for PC for use by fire managers. It will give summaries of fire, weather, and index values as well as probabilities of fire-day, large-fire-day, and multiple-fire-day for any given index value. It will produce tests of fit as a measure of which index and fuel model is best for a specific area. It will also guide users in determining critical decision points. The program will be designed so that ROC analysis can also be incorporated. The program will be tested by fire managers and revisions will be incorporated according to their suggestions.

The program will be adapted to a "batch" mode so that large volumes of data can be processed efficiently.

U.S. Analysis

In addition to providing a program that will allow fire managers to do an analysis to meet specific needs, we will do an analysis of the whole U.S. This will give an indication of which measures of fire danger perform best for various parts of the U.S. It will necessarily be a coarse analysis of zones of similar climate and fuel. This will be enough to satisfy some fire management needs. Additional more specific analyses can be done by fire managers as needed.

Fire Occurrence Data Base

It is necessary to have a national, interagency fire data base in order to do an analysis of the U.S. It would also be very useful for more specific studies. A small National Park, for example, may not have enough fires to obtain reliable probabilites.

The only information on fires that we have used to date is location, discovery date, final size, and cause. Various agencies may not have

similar information on their fire report forms, but everyone has that basic information. We have used Forest Service District as the location indicator for our Montana, California, and Mississippi studies. The Alaska fire data was sorted according to a specific area around a fire weather station. All location data should be in terms of lat/long. Conversion programs will be purchased and used to convert the data.

The interagency fire data base is needed by two other studies that are being proposed for DOI funding by scientists in RWU 4401. Bob Burgan will use it in his analysis of the use of NDVI satellite data for determining seasonal trends in live fuel for fire management. Don Latham will use it in testing an algorithm for probability of a fire start from a lightning strike. The data will likely be used for many other applications once it is available.

Each of the federal agencies has a fire data base, maintained separately. An interagency data base would only require that agency data be transferred to a central site once a year. Interagency data can be downloaded to an agency computer as needed.

State, rural, and private data will not be so easily obtained and handled. It will require some detective work to determine what is feasible.

The interagency fire weather data library will be housed at the Kansas City Computer Center. That may also be the location for WIMS, the Weather Information Management System. KCCC will be examined as a location for the interagency fire occurrence data base.

Cooperation

This study is just one of several studies being conducted by scientists in the Fire Behavior Research Work Unit. Cooperation among people involved in those studies will assure that results can be used both for current fire behavior and fire danger rating systems and also for the future integrated fire management system.

Because this research project has a need for the interagency fire data base, it is appropriate for us to see that it gets done. But there may be rules, regulations, and politics that will cause problems. We'll depend on others for assistance

We will coordinate our work with the Forest Service Fire and Aviation Management Systems group as well as Department of Interior (DOI) systems people through the technical contact for this agreement.

Determination of the analysis zones for the U.S. will be determined in conjunction with people who will use these zones for other purposes. This will also be coordinated with FS F&AM as well as DOI representatives.

We will coordinate our work on a training package for the FIRES program with the NWCG training team.

Because this system is based on NFDRS indexes, we will keep the NWCG National Advisory Group for Fire Danger Rating (NAGFDR) group informed of our plans and progress.

Because we plan to develop the next generation integrated fire management system in conjunction with the Canadians, we will keep the Canadian Fire Danger Working Group informed of our work.

Technology transfer

Publications will describe the technical aspects of logistic regression analysis, document examples of application of the methods, and explain how to use the program.

We will present overviews of the methods and applications to training sessions.

We will develop a self-study training package on use of the FIRES program.

PLANNED OUTPUTS/RESULTS

The following products will be produced under this cooperative agreement:

Publications
- General Technical Report on logistic regression methods
- Journal article on using logistic regression to test fire danger rating systems.
- Articles as appropriate on application of the methods
- User's manual on use of the PC program

Computer programs with technical documentation of the code.

Self-study training package for use of the PC program.

Analysis of the fire and index data for the whole U.S. by analysis zone.

Due Date	Product
12/31/92 06/30/93 12/31/93	Semi-annual written progress reports. Publications, computer code, etc. will be included as appropriate.
6/30/94	Final report, including computer code, technical documentation, user guide, and examples.
to be scheduled	Two formal presentations

PERSONNEL/COOPERATORS

Patricia L. Andrews	Forest Service Research; Fire Behavior Research Work Unit; Team Leader, Applied research team. Principal investigator Responsible for directing the study, writing papers, giving presentation, and assisting in program design.
Larry S. Bradshaw	Cooperator Research meteorologist/Systems Programmer Responsible for developing the computer programs, documenting the code, writing papers, giving presentations, and directing the work of the assistants.
Don O. Loftsgaarden	Cooperator Professor, mathematics Department, University of Montana. Responsible for development of statistical methods and documentation in technical papers.
Assistant	Responsible for running the program to do the U.S. analysis and producing example applications.
Assiatant	Responsible for developing the training package.
Assistant	Responsible for setting up the interagency fire data base and establishing procedures for future yearly updates.

The type of assistants will depend on the kind of hiring authority we have. Additional ceilings are necessary to hire temporary employees. Other possibilities are the use of detailers or contracts.

BUDGET

Amounts awarded to cooperators via Research Joint Venture Agreements (RJVA's) include cooperator overhead, fringe benefits, supplies, etc.

The Forest Service will cover salary of Forest Service employees (Andrews and support personnel) and RJVA for Loftsgaarden.

The following amounts include Forest Service Intermountain Research Station overhead-- 5% for RJVA's and 16% for the rest.

4/92 - 8/93	$75,000	Larry Bradshaw (RJVA)
9/92 - 8/93	$35,000	U.S. analysis, salary
9/92 - 9/93	$12,000	Training package development, salary
10/93- 8/93	$15,000	Interagency fire data base development, salary
4/92 - 8/93	$12,000	Travel
4/92 - 9/92	$15,000	Software (logistic analysis, graphics, lat/long conversion, etc.), data base transfer charges, etc.
Total	$164,000	

ENCLOSURES

1-- DOI Statement of Work

2-- Part of the Final Report "Application of NFDRS Indexes" submitted by Larry Bradshaw, Dec. 1990.
Includes a discussion of statistical methods, example applications, computer programs, system design recommendations, and literature citations.

3-- Office Report "Alaska: Fire Danger Rating--Fire Occurrence Analysis". by Andrews and Bradshaw.
Includes a comparison of the performance of the U.S. and the Canadian fire danger rating systems in Alaska, based on a limited data set.

4-- Table of contents of a General Technical Report that is expected to be published by Feb. 1992. "Constructing and Testing Logistic Regression Models for Binary Data: Applications to the National Fire Danger Rating System" by Loftsgaarden and Andrews.